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16. ABSTRACT

A national emission standard for glass manufacturing plants is being proposed under authority of Section 111 of the Clean Air Act. The purpose of the proposed standard is to minimize glass manufacturing furnace particulate emissions to the level attainable with best available control technology. The standard will have the effect of reducing uncontrolled emissions of particulate matter from these furnaces by about 90 percent. Environmental impact and economic impact statements quantifying the impacts of the proposed standard and alternative control options are included in the document.

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Glass Manufacturing Plants

Background Information: Proposed Standards of Performance

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1979

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1. SUMMARY

1.1 PROPOSED STANDARDS

This Background Information Document (BID) (formerly Standards Support and Environmental Impact Statement, or SSEIS) supports proposed standards for particulate emissions from glass melting furnaces within glass manufacturing plants. Atmospheric emissions from glass manufacturing plants, 98 percent of which originate from glass melting furnaces, include particulates, nitrogen oxides, and sulfur oxides. Demonstrated control technology exists only for particulates; therefore, the proposed standards of performance apply to particulates only. Additional information and regulatory rationale may be found in the preamble and regulation for Subpart CC in the *Federal Register*.

The glass manufacturing industry is divided into production categories based on industry definitions embodied in the Standard Industrial Classification (SIC) system. The division into categories based on the SIC system provided a basis for the economic analysis and also provided a basis for other analyses based on technical differences within the glass industry. There are four glass manufacturing industry SIC codes:

SIC 3211 - Flat glass
SIC 3221 - Container glass
SIC 3229 - Pressed and blown glass, not elsewhere classified (n.e.c.)
SIC 3296 - Wool fiberglass

In addition, SIC 3229 is sufficiently diversified to warrant a technical division into two subcategories based on glass formulation: (a) glass produced using soda-lime formulation, and (b) glass produced using other than soda-lime formulation.

The proposed emission standards would restrict particulate emissions from natural gas-fired glass melting furnaces to:

0.1 g/kg (0.2 lb/ton) of glass pulled from glass melting furnaces used for container glass production;

0.1 g/kg (0.2 lb/ton) of glass pulled from furnaces used for pressed and blown, n.e.c., glass production of soda-lime formulation;

0.25 g/kg (0.5 lb/ton) of glass pulled from furnaces used for pressed and blown, n.e.c., glass production of other than soda-lime formulation;

0.2 g/kg (0.4 lb/ton) of glass pulled from furnaces used for wool fiberglass production; and

0.15 g/kg (0.3 lb/ton) of glass pulled from furnaces used for flat glass production.

Although natural gas is the fuel traditionally used to fire glass melting furnaces, there is a growing trend toward use of fuel oil, which does not burn as cleanly as natural gas. Therefore, an increment of 15 percent over these emission limits is proposed for fuel oil-fired glass melting furnaces.

Control of particulate emissions from glass manufacturing plants is achieved by installation of an emission control system to remove particulate matter from the exhaust gas stream. Electrostatic precipitators (ESP) and fabric filters have been adequately demonstrated to be the best technological systems of continuous emission reduction for glass melting furnaces producing container glass; pressed and blown glass, n.e.c., of soda-lime formulation; pressed and blown glass, n.e.c., of other than soda-lime formulation; and wool fiberglass. No installed control systems have been evaluated for particulate emission reduction from flat glass installations; however, ESP are considered adequately demonstrated systems of emission reduction because of the similarity of processes used for flat glass and container glass production and because of a performance guarantee underwritten for a flat glass facility by an ESP manufacturer. These emission reduction methods are not equally applicable to glass melting furnaces in all sectors of the industry, hence the proposal of separate standards for each of the five production categories.

1.2 ENVIRONMENTAL IMPACT

The proposed emission limits would reduce particulate emissions from glass melting furnaces placed on line in glass manufacturing plants between 1978 and 1983 by 90-96 percent without adversely affecting water quality, solid waste disposal, energy conservation, or noise level. The environmental impacts of the proposed emission limits are summarized in Table 1-1.

1.3 ECONOMIC IMPACT

An economic impact assessment of the proposed emission limits has been prepared as required under Section 317 of the Clean Air Act (as amended in 1977). The proposed limits would have negligible impact on compliance costs, inflation or recession, competition with respect to small business, consumer costs, and energy use. The standards would reduce profitability (as measured by rate of return on assets) by approximately 0.2-0.8 percent. To offset this loss of return, glass manufacturers may increase prices by similar amounts.

The Agency's guideline for determining the necessity for developing an Inflationary Impact Statement is increased operating costs in the fifth year of operation of more than $100 million. The increase in operating costs in the fifth year associated with the proposed limits is about $10.4 million per year.

The economic impacts of the proposed emission limits are summarized in Table 1-1.

Table 1-1. MATRIC OF ENVIRONMENTAL AND ECONOMIC IMPACTS OF THE PROPOSED PARTICULATE EMISSION LIMITS

IMPACT / ACTION	Air	Water Pollution	Solid Waste	Energy	Noise	Economic	Inflationary
Option I (Proposed standards)	$+3^{xx}$	0	-1	-1^{xx}	0	-1^{xx}	-1^{xx}
Option II	$+2^{xx}$	-1^{xx}	-1	-1^{xx}	0	-1^{xx}	-1^{xx}
No Standards or Delayed Standards	0	0	0	0	0	0	0

Key:
+ Beneficial Impact
- Adverse Impact

0 No Impact
1 Negligible Impact
2 Small Impact
3 Moderate Impact
4 Large Impact

x Short-term Impact
xx Long-term Impact
xxx Irreversible Impact

2. INTRODUCTION

Standards of performance are proposed following a detailed investigation of air pollution control methods available to the affected industry and the impact of their costs on the industry. This document summarizes the information obtained from such a study. Its purpose is to explain in detail the background and basis of the proposed standards and to facilitate analysis of the proposed standards by interested persons, including those who may not be familiar with the many technical aspects of the industry. To obtain additional copies of this document or the Federal Register notice of proposed standards, write to EPA Library (MD-35), Research Triangle Park, North Carolina 27711. Specify "Glass Manufacturing Plants, Background Information: Proposed Standards of Performance," report number EPA-450/3-79-005a when ordering.

2.1 AUTHORITY FOR THE STANDARDS.

Standards of performance for new stationary sources are established under section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect, ". . . the degree of emission limitation achievable through the application of the best technological system of continuous emission reduction . . . the Administrator determines has been adequately demonstrated." In addition, for stationary sources whose emissions result from fossil fuel combustion, the standard must also include a percentage reduction in emissions. The Act also provides that the cost of achieving the necessary emission reduction, the nonair quality health and environmental impacts and the energy requirements all be taken into account in establishing standards of performance. The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions which apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources which have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

25 percent of the listed categories by August 7, 1980

75 percent of the listed categories by August 7, 1981

100 percent of the listed categories by August 7, 1982

A governor of a State may apply to the Administrator to add a category which is not on the list or to revise a standard of performance.

2. EPA is required to review the standards of performance every four years, and if appropriate, revise them.

3. EPA is authorized to promulgate a design, equipment, work practice, or operational standard when an emission standard is not feasible.

4. The term "standards of performance" is redefined and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low-polluting or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under section 111 of the Act is extended to six months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under section 116 of the Act to establish even more stringent emission limits than those established under section 111 or those necessary to attain or maintain the national ambient air quality standards (NAAQS) under section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area which falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means ". . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of 'best available control technology' result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to section 111 or 112 of this Act."

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling, and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, section 111(h) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require, or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare or safety; (4) the governor of the State where the source is located consents; and that, (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to three years to meet the standards, with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources which have not been listed before. The Adminstrator, ". . . shall include a category of sources in such list if in his judgement it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow while adhering to the schedule referred to earlier.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants which are emitted by stationary sources. Source categories which emit these pollutants were then evaluated and ranked by a process involving such factors as (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might be required from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented, in a pre-selected future year, by standards of performance for the source category. Sources for which new source performance standards were promulgated or are under development during 1977 or earlier, were selected on these criteria.

The Act amendments of August, 1977, establish specific criteria to be used in determining priorties for all source categories not yet listed by EPA. These are:

1) the quantity of air pollutant emissions which each such category will emit, or will be designed to emit;

2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and

3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

In some cases, it may not be feasible to immediately develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inablility to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, determining the types of facilities within the source category to which the standard will apply must be decided. A source category may have several facilities that cause air pollution and emissions from some of these facilities may be insignificant or very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there be no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, and the nonair quality health and environmental impacts and energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction which has been adequately demonstrated. The legislative history of section 111 and various court decisions make clear that the Administrator's judgement of what is adequately demonstrated is not limited to systems that are in actual routine use. The search may include a technical assessment of control systems which have been adequately demonstrated but for which there is limited operational experience. In most cases, determination of the ". . . degree of emission reduction achievable . . ." is based on results of tests of emissions from well-controlled existing sources. At times, this has required the investigation and measurement of emissions from control systems found in other industrialized countries that have developed more effective systems of control than those available in the United States.

Since the best demonstrated systems of emission reduction may not be in widespread use, the data base upon which standards are developed may be somewhat limited. Test data on existing well-controlled sources are obvious starting points in developing emission limits for new sources. However, since the control of existing sources generally represents retrofit technology or was originally designed to meet an existing State or local regulation, new sources may be able to meet more stringent emission standards. Accordingly, other information must be considered before a judgement can be made as to the level at which the emission standard should be set.

A process for the development of a standard has evolved which takes into account the following considerations:

1. Emissions from existing well-controlled sources as measured.

2. Data on emissions from such sources are assessed with consideration of such factors as: (a) how representative the tested source is in regard to feedstock, operation, size, age, etc.; (b) age and maintenance of control equipment tested; (c) design uncertainties of control equipment being considered; and (d) the degree of uncertainty that new sources will be able to achieve similar levels of control.

3. Information from pilot and prototype installations, guarantees by vendors of control equipment, unconstructed but contracted projects, foreign technology, and published literature are also considered during the standard development process. This is especially important for sources where "emerging" technology appears to be a significant alternative.

4. Where possible, standards are developed which permit the use of more than one control technique or licensed process.

5. Where possible, standards are developed to encourage or permit the use of process modifications or new processes as a method of control rather than "add-on" systems of air pollution control.

6. In appropriate cases, standards are developed to permit the use of systems capable of controlling more than one pollutant. As an example, a scrubber can remove both gaseous and particulate emissions, but an electrostatic precipitator is specific to particulate matter.

7. Where appropriate, standards for visible emissions are developed in conjunction with concentration/mass emission standards. The opacity standard is established at a level that will require proper operation and maintenance of the emission control system installed to meet the

concentration/mass standard on a day-to-day basis. In some cases, however, it is not possible to develop concentration/mass standards, such as with fugitive sources of emissions. In these cases, only opacity standards may be developed to limit emissions.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires, among other things, an economic impact assessment with respect to any standard of performance established under section 111 of the Act. The assessment is required to contain an analysis of:

(1) the costs of compliance with the regulation and standard including the extent to which the cost of compliance varies depending on the effective date of the standard or regulation and the development of less expensive or more efficient methods of compliance;

(2) the potential inflationary recessionary effects of the standard or regulation;

(3) the effects on competition of the standard or regulation with respect to small business;

(4) the effects of the standard or regulation on consumer cost; and,

(5) the effects of the standard or regulation on energy use.

Section 317 requires that the economic impact assessment be as extensive as practicable, taking into account the time and resources available to EPA.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical existing State control regulations. An incremental approach is taken since both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the impact upon the industry resulting from the cost differential that exists between a standard of performance and the typical State standard.

The costs for control of air pollutants are not the only costs considered. Total environmental costs for control of water pollutants as well as air pollutants are analyzed wherever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made. It is also essential to know the capital requirements placed on plants in the absence of Federal standards of performance so that the additional capital requirements necessitated by these standards can be placed in the proper perspective. Finally, it is necessary to recognize any constraints on capital availability within an industry, as this factor also influences the ability of new plants to generate the capital required for installation of additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal Agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all enviornmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, Federal Courts of Appeals have held that environmental impact statements need not be prepared by the Agency for proposed actions under section 111 of the Clean Air Act. Essentially, Federal Courts of Appeals have determined that ". . . the best system of emission reduction, . . . require(s) the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. . ." On this basis, therefore, the Courts ". . . established a narrow exemption from NEPA for EPA determination under section 111."

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969."

The Agency has concluded, however, that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, while not legally required to do so by section 102(2)(C) of NEPA, environmental impact statements will be prepared for various regulatory actions, inlcuding standards of performance developed under section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are identified and discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new sources as ". . . any stationary source, the construction or modification of which is commenced . . . " after the proposed standards are published. An existing source becomes a new source if the source is modified or is reconstructed. Both modification and reconstruction are defined in amendments to the general provisions of Subpart A of 40 CFR Part 60 which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416). Any physical or operational change to an existing facility which results in an increase in the emission rate of any pollutant for which a standard applies is considered a modification. Reconstruction, on the other hand, means the replacement of components of an existing facility to the extent that the fixed capital cost exceeds 50 percent of the cost of constructing a comparable entirely new source and that it be technically and economically feasible to meet the applicable standards. In such cases, reconstruction is equivalent to a new construction.

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under section 108 or which has not been listed as a hazardous pollutant under section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, section 111 of the Act provides that the Administrator ". . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3.0 THE GLASS MANUFACTURING INDUSTRY

3.1 GENERAL

3.1.1 INTRODUCTION

This chapter presents prominent features of the glass manufacturing industry including a description of the glass producing processes and a discussion of atmospheric emissions. This chapter focuses primarily on particulate matter emitted from the glass melting furnace. Other emissions are discussed briefly.

3.1.2 GLASS MANUFACTURING INDUSTRY STATISTICS

The glass manufacturing industry is classified in accordance with the industry definitions embodied in the Standard Industrial Classification (SIC) system. Under this system of classification, an industry is generally defined as a group of establishments producing a single product or a more or less closely related group of products. Accordingly, for the glass industry there are four SIC codes:

SIC 3211 — Flat glass
SIC 3221 — Container glass
SIC 3229 — Pressed and blown glass, not eleswhere classified (N.E.C.)
SIC 3296 — Wool fiberglass

Glass manufacturing facilities are located throughout the United States and are usually situated in areas that ensure the availability of raw materials. These plants are found in 34 states with almost three-quarters of these plants in the following 10 states: California, Illinois, Indiana, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Texas, and West Virginia. In early 1978 there are 129 primary glass-producing companies which together operate 338 individual plants. Placing these plants in SIC categories, there are 32 flat glass plants (SIC 3211); 117 container glass plants

(SIC 3221); 165 pressed and blown, N.E.C., plants including 13 textile fiberglass plants (SIC 3229); and 24 wool fiberglass plants (SIC 3296). Appendix D lists, by state, individual glass plants and the SIC designations for each plant.[1,2,3,4,5]

Recent production rates and dollar values of shipments for each segment of the industry are summarized in Table 3-1.[6,7,8,9,10,11,12] A significant result of these statistics shows that, assuming 77 percent of glass produced in the pressed and blown is soda-lime glass as it was in 1973,[13] over 90 percent of the total glass produced in 1976 is soda-lime glass. Additionally, the figures on this table form the bases of the industry growth predictions derived in Section 3.1.3.

3.1.3 INDUSTRY GROWTH PROJECTIONS

In this section, the anticipated growth of the glass industry is estimated by a straight line formulation used in previous glass manufacturing projections.[14] Table 3-2 presents the projected weight of glass produced in 1985 by each segment of the industry. The annual growth rates used in these calculations were determined in a previous study and reflected the growth, from 1958 to 1972, of the dollar value of glass products corrected for inflation.[15] Although these corrected dollar values do not strictly apply to the weight of the glass produced, it is assumed that, within the accuracy of the projection scheme, these annual growth rate dollar values can be used to predict glass weight production rates for the period from 1976 to 1985.

3.2 GLASS MANUFACTURING PROCESSES AND THEIR EMISSIONS

Although there are numerous unit operations used in the manufacturing of glass, most key processing steps, which generate the largest amounts of atmospheric emissions, are common throughout the industry. In this subsection, the basic operations and the

Table 3-1. 1976 PRODUCTION RATES AND VALUES OF SHIPMENTS

Segment	SIC Code	Production Rate in 1976[a]	Dollar Value of Shipments in 1976 (In Millions of Dollars)
Flat Glass	3211	2.56 Tg (2.91 MM Tons)[6]	645[7]
Container Glass	3221	11.8 Tg (13.0 MM Tons)[8]	3,251[9]
Pressed and Blown (N.E.C.)	3229	1.73 Tg (1.95 MM Tons)[6]	1,598[10]
Wool Fiberglass	3296	0.896 Tg (0.986 MM Tons)[11]	817[12]

[a] Tg is an abbreviation for 10^{12} grams. MM tons represents one million tons.

Table 3-2. PROJECTED 1985 PRODUCTION RATES

Segment	SIC Code	Annual Growth Rate (Percent)	1985 Production Rate	
			Tg	(MM Tons)
Flat	3211	1.8[16]	3.1	(3.4)
Container	3221	3.1[16]	15.0	(17.0)
Pressed and Blown (N.E.C.)	3229	3.5[16]	2.3	(2.5)
Wool Fiberglass	3296	7.1[17]	1.5	(1.6)

major pollutants they emit are identified and assessed. Special types of unit operations or additional pollutants which significantly affect the total emissions of the primary glass industry are discussed.

3.2.1 BASIC PROCESS

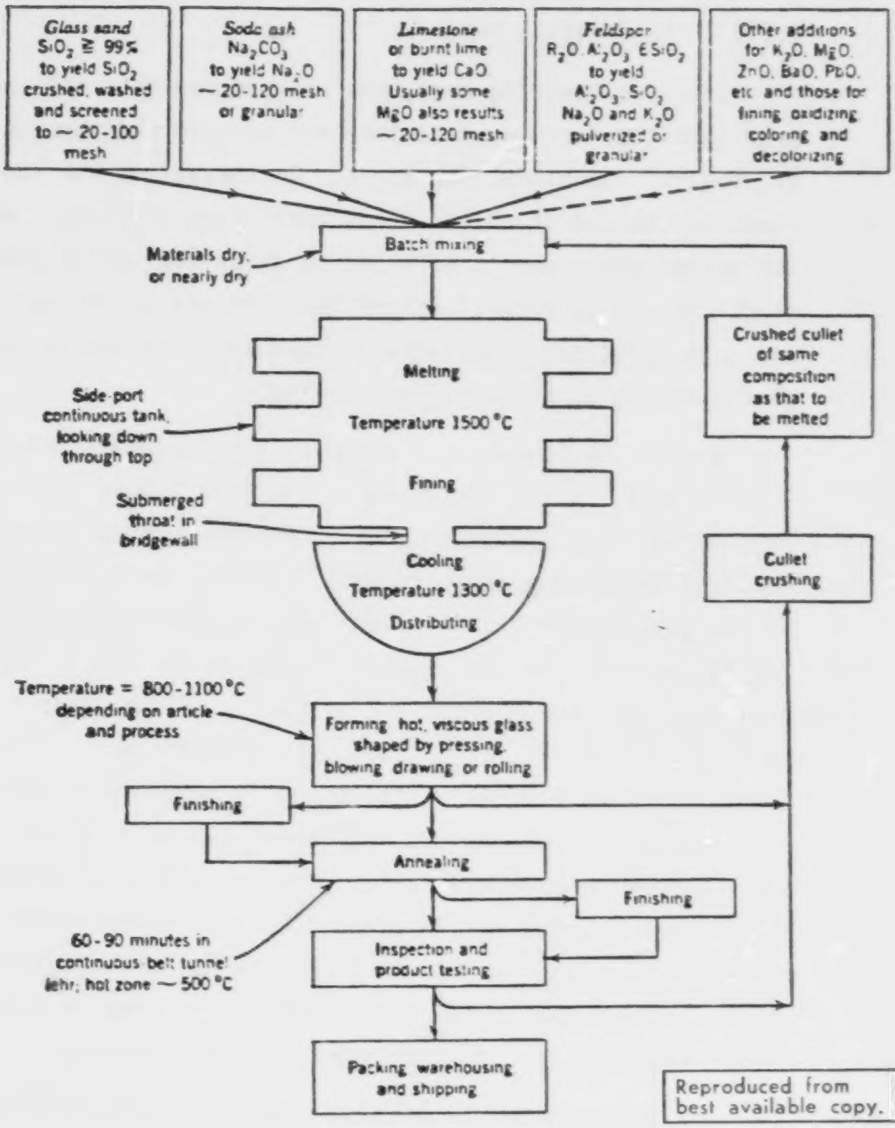
Glass is manufactured in a high temperature conversion of raw materials into a homogeneous melt capable of fabrication into useful articles. This process can be broken down into three subprocesses: raw material handling and mixing; melting; and forming and finishing. Emission points within each subprocess are discussed in Section 3.2.2. Figure 3-1 gives a typical flow diagram for the manufacture of soda-lime glass;[18] however, it has general application to other commercial glass formulations.

3.2.1.1 Raw Material Handling and Mixing

The raw materials are received in packages or in bulk and are unloaded by hand, vibrator-gravity, drag shovels, or vacuum systems. Cullet, crushed recycled glass, must be segregated and transferred to storage bins by various processes including the utilization of bucket elevators, belt conveyors, or screw conveyors. In addition to bulk raw materials, certain minor constituents are packaged and stored in their original containers until mixed with the batch.

Prior to being fed into the melting unit, the raw materials are mixed according to the desired product recipe. Weighing and mixing operations may be automated or carried out by hand depending on the size or specialty of the operation. The melters themselves are charged manually or automatically, usually through screw or reciprocating-type feeders.

Emissions generated in raw material and handling processes are discussed in Section 3.2.2.1.


Glass sand
SiO2 ≧ 99%
to yield SiO2
crushed, washed
and screened
to ~ 20-100
mesh
Soda ash
Na2CO3
to yield Na2O
~ 20-120 mesh
or granular
Limestone
or burnt lime
to yield CaO
Usually some
MgO also results
~ 20-120 mesh
Feldspar
R2O·Al2O3·6SiO2
to yield
Al2O3, SiO2
Na2O and K2O
pulverized or
granular
Other additions
for K2O, MgO,
ZnO, BaO, PbO,
etc. and those for
fining, oxidizing,
coloring, and
decolorizing
Batch mixing
Materials dry,
or nearly dry
Melting
Temperature 1500 °C
Fining
Side-port
continuous tank,
looking down
through top
Submerged
throat in
bridgewall
Cooling
Temperature 1300 °C
Distributing
Crushed cullet
of same
composition
as that to
be melted
Cullet
crushing
Temperature = 800-1100 °C
depending on article
and process
Forming: hot, viscous glass
shaped by pressing,
blowing, drawing, or rolling
Finishing
Annealing
Finishing
60-90 minutes in
continuous belt tunnel
lehr; hot zone ~ 500 °C
Inspection and
product testing
Packing, warehousing,
and shipping

Reproduced from
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Figure 3-1. Typical Flow Diagram for the Manufacture of Soda-Lime Glass

Reproduced from Encyclopedia of Chemical Technology, 2nd Edition,
Volume 10, pg. 549, 1966

3.2.1.2 The Melting Process

From the handling area, the weighed raw materials are delivered into the furnace where they are transformed through a sequence of chemical reactions into glass. In operation, the raw materials float on the bed of molten glass until they dissolve. Mixing in the molten glass bed is effected by gases evolved in chemical reactions and by natural convection currents in the molten glass bed. In addition, some furnaces have air injected in the bottom of the bed to augment ebulient mixing.

Within the temperature range of the furnace (nominally 1,500°C to 1,700°C), the glass exists as a liquid free of crystalline matter with a viscosity of 10 Newton-seconds per square meter ($N\text{-}s/m^2$) which is equivalent to 100 poise. Because the viscosity of the glass exiting the furnace must be compatible with the forming operations, the temperature of the molten bed is decreased gradually to a point until the viscosity of the glass is about 100 to 1,000 $N\text{-}s/m^2$ (10^3-10^4 poise). In addition to cooling as it flows through the furnace, the glass is retained in the furnace long enough so that gaseous inclusions can be removed. From the introduction of raw materials to the extraction of a homogeneous melt suitably ready for forming, a furnace accomplishes three functions in glassmaking: to bring raw materials together to react; to hold the molten glass until it is free of bubbles and inclusions; and to condition the glass for forming.

Energy required for melting glass is supplied by burning either natural gas or fuel oil and sometimes by augmenting the energy produced from these fossil fuels with electricity which is converted to heat within the liquid glass bed. A recent study[19] shows that these three energy sources provide over 99 percent of the energy consumed in the industry. Although this study inventories all energy utilized and therefore includes energy expended on processes other than melting, consumption of energy in the furnace predominates consumption in all other areas. Data for 1976 show that natural gas provides 74 percent of the energy, fuel oil 14 percent, and electricity 11 percent. Natural gas has been the preferred primary fuel with fuel oil used when natural gas supplies were curtailed. This pattern is expected to change soon with fuel oil becoming the predominant fossil fuel used in furnace firing. Coal is not presently burned or gasified to provide heat to the glass industry. Although a successful pilot study has been made,[20] coal is not expected to supply a significant amount of energy to the industry in the future.

There are three types of fossil fuel-fired melting units used in the glass industry: day pots, day tanks, and continuous tanks. Typically, day pots are used where other larger tanks are not economically justified because of limited production of special compositions of glass. The range of the capacities of day pots varies from 9 kilograms (20 pounds) to 1,800 kilograms (2 tons) with these quantities melted in 24-hour batches. Although the capacity of a typical day tank is slightly larger than that of a typical day pot, the primary distinction between the two units is the material of construction of the vessel walls.

Although day pots and day tanks are used to produce glass, most glass tonnage is melted in larger capacity, continuously operating regenerative or recuperative furnaces. Of these two, there are more regenerative units producing glass than recuperative units. Generally, regenerative furnaces maintain a larger production rate than recuperative furnaces. These types of furnaces differ in the types and modes of operation of the heat exchangers used to recover heat from the furnace exhaust gases.

Regenerative furnaces utilize two chambers of refractory called checkerworks in the following manner: at any one time, while combustion flue gases heat the refractory in one checkerwork chamber, the other checkerwork preheats combustion air; then after intervals ranging from 10 to 30 minutes, this gas flow is diverted so that combustion air is drawn through the chamber previously heated by flue gases, and flue gases heat the refractory in the other chamber previously used to preheat combustion air. Regenerative furnaces, themselves, are divided into two functional categories — side-port and end-port furnaces depending on the furnace flame firing pattern. Figure 3-2 illustrates a typical side-port furnace (called "side-fired" in the figure) and an end-port furnace (called "end-fired" in the figure).

Recuperative furnaces employ one continuously operating shell and tube type heat exchanger to preheat combustion air instead of the checkerwork heat exchangers used in regenerative furnaces.

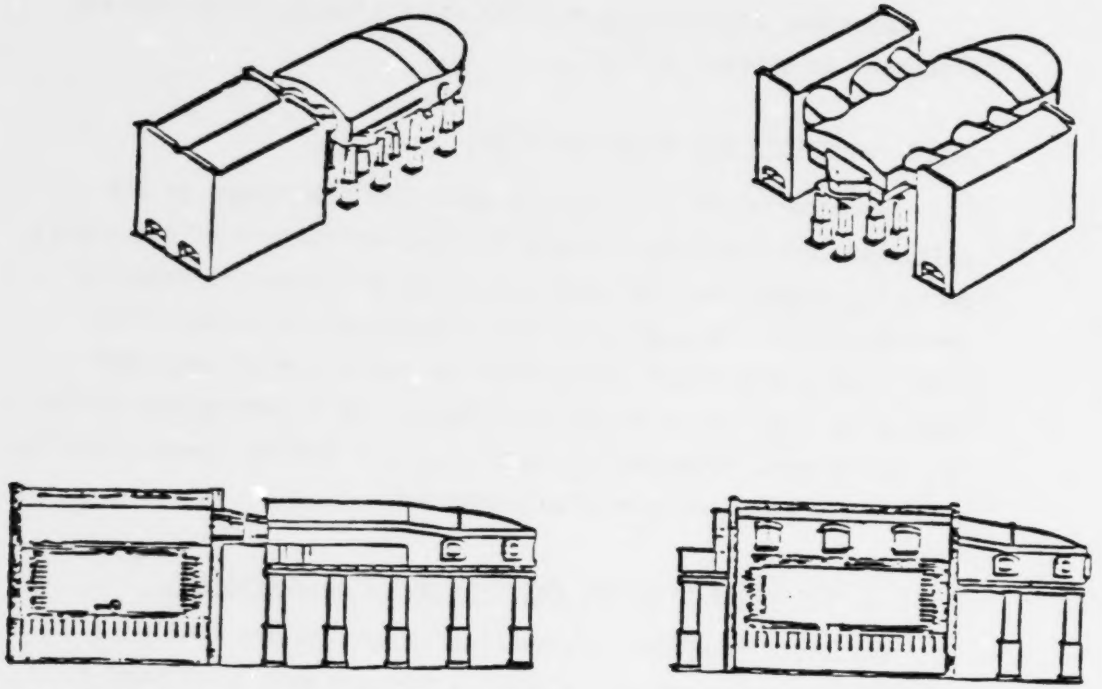
In existing furnaces where fossil fuel provides the bulk of energy consumed, electricity is often used to supply energy needed to increase production. Additionally, in specially designed furnaces called "all-electric melters," electricity has also been used as the sole energy source for glass production after the liquefaction of a glass bed.

The significant emission point in glass melting furnace operations is the stack where combustion gases are released to the atmosphere. Emissions generated in melting furnaces are discussed in Section 3.2.2.2.

3.2.1.3 Forming and Finishing

In the forming and finishing step, the molten glass is extracted from the furnace, shaped to the desired form, and then annealed at high temperature. The final product is then either inspected and shipped or sent for further finishing such as tempering or decorating.

In practice, the molten glass, while at a yellow-orange temperature, is drawn quickly from the furnace and worked in forming



END-FIRED BOX TYPE REGENERATOR GLASS FURNACE

SIDE-FIRED BOX TYPE REGENERATOR GLASS FURNACE

Figure 3-2. Typical Side-Port Furnace and End-Port Furnace

Courtesy of G.P.I.

machines by a variety of methods: pressing; blowing in molds; and drawing, rolling, and casting. Immediately, this formed glass is conveyed to continuous annealing ovens to remove internal stresses in the glass by controlled cooling. Figure 3-3,[21] illustrates a typical forming operation in the glass container industry.

Emissions generated in forming and finishing operations are discussed in Section 3.2.2.3.

3.2.2 PROCESSES AND THEIR EMISSIONS

The material in this section describes the nature of air pollutants generated in the uncontrolled manufacture of glass products and quantifies the levels of these pollutants released to the atmosphere. As substantiated in these sections, emissions from furnace operations are greater by two orders of magnitude than those from raw material handling and from forming and finishing operations. Examples of regulations of several states limiting particulate emissions are also presented.

3.2.2.1 Emissions From Raw Material Handling Operations

Emissions from this glassmaking subprocess are limited to solid particles becoming airborne in the movement or storage of bulk raw materials. Since no chemical reactions occur between these materials at ambient conditions, the chemical composition of the fugitive dusts is the same as the raw materials from which they were entrained.

The glass industry uniformly contains fugitive dust emissions by enclosing the unloading and conveying areas and controls them by venting storage areas through fabric filters. Because the emission factors for controlled raw material handling operations are, on the average,[22,23,24] two orders of magnitude less than those for glass melting, these fugitive emissions will not be discussed further.

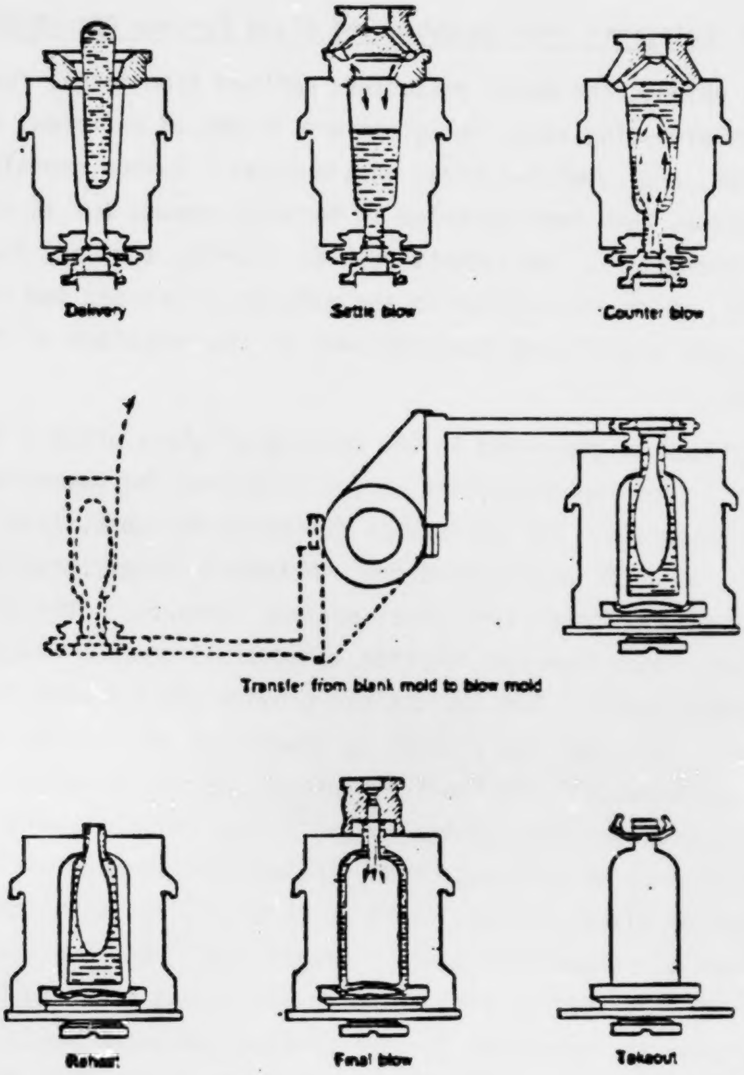

Delivery
Settle blow
Counter blow
Transfer from blank mold to blow mold
Reheat
Final blow
Takeout

Figure 3-3. Example of One Type of Forming Used in Container Glass Production

Reproduced from Encyclopedia of Chemical Technology, 2nd Edition, Volume 10, pg. 559, 1966

3.2.2.2 Emissions From Uncontrolled Glass Furnace Operations

By weight, the major pollutants emitted from fossil fuel-fired furnaces producing soda-lime glass are oxides of nitrogen, oxides of sulfur, and submicron-sized particulates. Carbon monoxide and hydrocarbons have been detected in furnace exhaust but in much lesser quantities. Pollutants such as arsenic, borates, fluorides, and lead, which are emitted in the exhaust of pressed and blown glass, make significant contributions to the emissions of the glass industry.

Pollutants generated in the melting of glass arise from two sources: from the combustion of fuel and from the vaporization of raw materials. The pollutants formed in the combustion of fuel are NO_x, SO_x, CO, and hydrocarbon. Nitrogen oxides constitute the largest mass emission from glass melting furnaces. This gas phase pollutant forms from the reaction between nitrogen and oxygen at high temperatures. Two sources can provide the nitrogen for the reaction: nitrogen gas present in combustion air and nitrogen contained chemically in the fuel burned. Values taken from the National Emission Data System (NEDS)[25] show emissions varying from less than 1 up to 10 grams of NO_x (calculated at NO_2) emitted per kilogram of glass produced (2 to 20 lb/ton). The emissions for container glass and flat glass averaged 3.94[26] and 3.82 g/kg NO_2[27] (7.88 and 7.64 lb/ton) with standard deviations close to 3 g/kg (6 lb/ton); the emissions for the pressed and blown sector averaged to a value of 4.24 g/kg[28] (8.50 lb/ton) with a standard deviation of about 2 g/kg (4 lb/ton). Standard deviation is an index of the dispersion of data about the average value; two-thirds of the data cluster within one standard deviation on both sides of the average value. The few NO_x emissions reported for fiberglass fall within the above range of values (1 to 10 grams per kilogram). The amount of nitric oxide being formed in a glass melting furnace may vary among glass formulations; the formulations requiring higher firebox temperatures generate more nitric oxide than those formulations needing lower temperatures.

Some of the sulfur oxides emitted from the manufacture of glass are caused by the oxidation of sulfur compounds in the fossil fuels. All of the source assessment authors for the different categories of the glass industry state that sulfur present in fuel oil leaves the glass melting furnace as SO_2.[29,30,31] Figures reported in the literature estimate that a fuel oil containing 1 percent sulfur by weight will yield approximately 600 ppm of SO_2 in the flue gas.[32] The authors also note that since the NEDS data were measured when natural gas was universally used as a glass melting fuel, the effect of shifting fuels from natural gas (with no sulfur) to fuel oil will be increased sulfur dioxide emissions. The remainder of the SO_2 emissions form from the volatization and reaction of raw materials and will be discussed later with other pollutants from that source.

Both carbon monoxide and hydrocarbon emissions from glass producing furnaces are due primarily to the incomplete combustion of fossil fuel and, additionally, to the decomposition of powdered coal added to the batch materials. With highly efficient furnace operating practices uncontrolled emission rates of these pollutants have been kept at low levels. Established emission factors for CO for flat, container, and pressed and blown glass production are: 0.02 g/kg (0.04 lb/ton),[33] 0.06 g/kg (0.12 lb/ton),[34] and 1.10 g/kg (2.20 lb/ton),[35] respectively. Emission factors for hydrocarbons are reported to be 0.04 g/kg (0.08 lb/ton),[36] 0.08 g/kg (0.16 lb/ton),[37] and 0.15 g/kg (0.30 lb/ton),[38] respectively, for these types of glass production. It is reported that both CO and hydrocarbon emission factors should be independent of the type of glass produced.

The other source of air pollutants from the glass melting furnace is the vaporization of raw materials from the glass melt.

The major raw materials used in all types of glass manufacturing are:glass, sand, soda, ash, limestone, and cullet. (Cullet consists of recycled, crushed glass.) Typical raw material batch recipes for several types of product glasses are given in Table 3-3.[39]

The common oxides listed in the table can be categorized as formers, fluxes, and stablizers. By themselves, formers account for the random three-dimensional atomic structure characteristic of glass. Fluxes are added to lower the melting points and the working temperatures which must be maintained in the furnace. Stabilizers improve the chemical durability of the glass product by lowering the coefficient of expansion and preventing glass crystallization. Of the raw materials listed in Table 3-3, the borates increase the thermal durability of the glass product by lowering the coefficient of expansion; lead increases the refractive index and density; aluminum increases glass strength; feldspar, reportedly, lowers the mixture melting point and prevents devitrification; sodium accelerates the melting process; and arsenic compounds aid in fining (removing bubbles from the melt). In addition to these compounds, trace amounts of various metal oxides are added to the batch to change the color of the glass by either imparting a color or neutralizing the tints caused by batch contaminants.

These raw materials react in the molten bed of soda-lime glass in the furnace releasing carbon dioxide in the following proposed reaction sequence:[40]

$$Na_2CO_3 + \alpha SiO_2 \longrightarrow Na_2O \bullet \alpha SiO_2 + CO_2$$

$$CaCO_3 + \beta SiO_2 \longrightarrow CaO \bullet \beta SiO_2 + CO_2$$

$$Na_2SO_4 + \gamma SiO_2 + C \longrightarrow Na_2O \bullet \gamma SiO_2 + CO + SO_2$$

Table 3-3. RAW MATERIAL BATCH RECIPES

Raw Material	Weight in Soda-Lime Container Glass	Weight in Soda-Lime Sheet Glass	Weight in Boro-silicate Glass	Weight in Lead Crystal
Sand (SiO_2)	2,000	2,000	2,000	2,000
Limestone ($CaCO_3$)	490	50		
Dolomite ($CaCO_3 \bullet MgCO_3$)		480		
Soda Ash (Na_2CO_3)	650	680		
Potassium Carbonate (K_2CO_3)				290
Red Lead (Pb_3O_4)				1,310
Nepheline Syenite (25% Al_2O_3; 15% Na_2O; 60% SiO_2)	200		190	
Felspar ($K_2O \bullet Al_2O \bullet 6SiO_2$)		150		
Anhydrous Borax ($Na_2O \bullet 2B_2O_3$)			350	
Boric Acid ($B_2O_3 \bullet 3H_2O$)			230	
Sodium Sulfate ($Na_2 SO_4$)	15	60		
Sodium Nitrate ($NaNO_3$)	15		0.5	
Sodium Chloride ($NaCl$)			1	
Arsenious Oxide (As_2O_3)			1	
Carbon (C)		3		
Total Weight	3,370	3,423	2,772.5	3,600

Note: Weight of materials is measured in pounds based on 2,000 pounds of dry sand.

As mentioned previously, chemical side reactions occurring in the furnace lead to the formation of gaseous sulfur oxides from sodium sulfate. The proposed pathway is:[41]

$$Na_2SO_4 \xrightarrow{1000°C} Na_2O + SO_3$$

The major type of air pollutant released in glass melting is particulate which vaporizes from the molten glass surface and condenses at lower temperatures in the checkerwork or in the stack. Since testing of this particulate shows no silica compounds, no contribution to the particulate emissions by raw materials being entrained in the flue gases and then being swept from the furnace is made by batch carryover. Testing does show that the largest percentage of the particulate from soda-lime glass is sodium sulfate which is predicted in the following reaction sequence.[42]

$Na_2O + H_2O \longrightarrow 2NaOH$ (occurring in a vapor state over the melt)

$SO_2 + 1/2\ O_2 \longrightarrow SO_3$ (occurring in a vapor state over the melt)

$2NaOH + SO_3 \longrightarrow Na_2SO_4 + H_2O$ (occurring in a checker or exhaust system with the product in a liquid state)

The submicron size distribution of the particulate reinforces the condensation mechanism. In general, testing shows that over 75 percent of the particualte catch has a characteristic size of less than one micron.[43]

As with soda-lime glass, the chemical composition of the particulate emitted from the manufacturing of other formulations of glass depends on the raw materials processed through the furnace. The particualte emitted in borosilicate glass manufacture consists of boric acid and alkali borates. In the production of opal glass B_2O_3, NaF, and Na_2SiF_6 appear in the particulate catch. For lead glass production in a natural gas-fired furnace, the chemical composition of the particulate is lead oxide and lead sulfate.[44] Although the use of arsenic as a fining and decolorizing agent in flat and container glass has been reduced, arsenic is still used where it is required in the product specifications for glasses classified as pressed and blown products. Arsenic has also been assayed in small levels in the particulate emitted from these furnaces.[45] Boron and fluoride compounds are also found in the melting furnace emissions from wool and textile fiberglass manufacturing.[46] Of the fluorine fed to the furnace in the raw materials, some may leave as a gaseous compound, HF, or as a particulate. The fluoride species which have been detected are: HF, NaF, PbF_2, BF_3, SiF_4, and Na_2SiF_6.[47] In recent testings of uncontrolled glass furnaces, up to 10 percent of the fluorine added in the feed was measured in the furnace exhaust.[48]

In addition to the nature of particulate emissions, depending on the kinds and amounts of raw materials fed to the furnace, operating parameter values affect the levels of pollutants emitted from the glass furnace. Key operating parameters are: the furnace (or bridgewall) temperature, the amount of cullet in the raw batch, the use of electric boosting, the surface area of the molten glass bed, the production (or pull) rate of glass exiting the furnace, and the type of fuel being burned. Of these operational variables for a fixed glass composition, temperature is the signal parameter. Increasing the temperature over the melt vaporizes more of the volatile materials than at lower temperatures. Maintaining high temperature requires more fuel to be consumed and should, therefore, increase the levels of pollutants derived from fossil fuels — NO_x and, if sulfur containing fuel oil is burned, SO_x. Other parameters previously listed influence pollutant emission levels by changing the temperature required to maintain production. For example, increasing the cullet proportions in the raw batch lowers bridgewall temperature, thereby, lowering emissions. In the same way, electric boosting lowers the furnace temperature required to maintain glass production thereby resulting in less emissions than at an identical production rate without electric boosting.

The amount of surface area of molten glass exposed to combustion gases has been shown to affect particulate emissions. With all other parameters constant, a larger exposed area generates more particulate than a smaller area.[49]

For a furnace producing a single type of glass, increasing the pull rate requires more energy, which if supplied by the combustion of fossil fuels, causes an increase in furnace temperature with a concomitant increase in emissions. The dependence of emission rates on furnace throughput is well established. This dependence is incorporated within the compliance regulations of several states. These compliance regulations show an exponential dependence of less than one for the weight rate emissions versus weight throughput rate, indicating that particulate emissions per kilogram of glass produced decrease as production rate increases. In the limiting case of no pull rate, data have been published which show that particulates are still emitted from the molten glass bed.[50] For this case, the emission levels at zero pull rate were roughly 20 percent of those at the normal pull rate with both measurements being taken at the same temperature.

The glass manufacturing industry is divided into natural categories which basically follow the Standard Industrial Classifications. This classification differentiates the following glass manufacturing types: Flat Glass, Container Glass, Pressed and Blown Glass (including glass products not classified elsewhere), and the Wool Fiberglass portion of SIC 3296. Examples of end-products from each classification are listed in Appendix E.

Of these SIC designations only the Pressed and Blown classification needs to be modified to adequately describe the industry. Based on amounts of particulate emitted from melting furnaces, two glass formulation types are distinguishable — a type consisting of soda-lime formulations and a type comprising the remaining glass formulations in this SIC (borosilicate, opal, lead, and other glass formulations). Based on information from the glass industry, two Pressed and Blown model plant production rates characterize the facilities in this SIC. The production rates correspond to small and moderate size glass melting furnaces. The glass formulation types are utilized in this subsection to quantify the uncontrolled melting furnace emissions and in Chapter 6.0 to set regulatory options. The production rate characterizations are used in Chapter 7.0 to determine environmental impacts.

Gaseous and particulate emissions from uncontrolled glass melting furnaces are depicted in Table 3-4 for each industry category. Values of gaseous emissions are taken from source assessment documents.[51,52,53,54,55] Particulate emissions are based:on the results of emission tests performed for the EPA; on the results of emission tests provided by the glass industry in response to questionnaires; and on the emissions reported in source assessments of the screening of study documents.

From emission test results of Flat Glass furnaces,[56] particulate emissions range from roughly 0.9 grams per kilogram of glass produced to roughly 1.1 g/kg (1.8 to 2.2 lb/ton). The table entry of 1.5 g/kg (3.0 lb/ton) represents a conservative numerical value of emissions from this industry category. For the Container Glass category, the tabled value of 1.25 g/kg (2.5 lb/ton) reflects the average value of 1.15 g/kg (2.3 lb.ton) measured in eight uncontrolled Container Glass melting furnaces.[57] Based on the similarity of the glass formulation of soda-lime glass manufactured in Pressed and Blown furnaces as compared with that of soda-lime glass manufactured in Container furnaces and based on the equivalence of furnace configurations and sizes in these two glass manufacturing categories, the particulate emissions for the Pressed

Table 3-4. EMISSIONS FROM UNCONTROLLED GLASS MELTING FURNACES FOR EACH INDUSTRY CATEGORY

Industry Category	NO_x		Particulate		SO_x		CO		Hydrocarbon		Fluorides		Selenium	
	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)
Flat glass[a]	4.0	(8.0)	1.5	(3.0)	1.5	(3.0)	(0.02)	(0.04)	0.04	(0.08)				
Container glass[b]	2.3	(4.6)	1.25	(2.5)	1.4	(2.8)	.085	(.17)	.0685	(.13)			0.002	(0.004)
Pressed and Blown: soda-lime[c]	4.25	(8.5)	1.25	(2.5)	2.68	(5.36)	.10	(.20)	.15	(.30)				
Pressed and Blown: other than soda-lime[d]	N.R.		5	(10)	2.99	(5.98)	N.R.		N.R.		10	(20)		
Wool fiber-glass[e]	2.5	(5.0)	5	(10.0)	5.	(10.0)	.125	(.25)	N.R.		.06	(.12)		

N.R. - not reported

[a] Emissions of NO_x, SO_x, CO, HC from reference 51

[b] Emissions of NO_x, SO_x, CO, HC, Se from reference 52

[c] Emissions of NO_x, SO_x, CO, HC from reference 53

[d] Emissions of SO_x and F from reference 54 and based on the following weight fractions: borosilicate 47.8%, opal 30.4%, and lead 21.7%.

[e] Emissions of NO_x, SO_x, CO, F from reference 55

and Blown: soda-lime category match that of the Container Glass category. This matching is substantiated in an emission test.[58] For the Pressed and Blown: other than soda-lime category, EPA emission test results and emissions reported in the source assessment vary considerably. The emission test results from the EPA program range from 3.2 to 3.5 g/kg (6.4 to 7.0 lb/ton),[59] while the source assessment values are an order of magnitude higher.[60] The table entry of 5 g/kg (10 lb/ton) reflects the EPA value. Lastly, for the Wool Fiberglass category, the particulate emissions correspond to the value reported for regenerative furnaces in the screening study.[61]

As is the case with gaseous pollutants, switching combustion sources from natural gas to fuel oil affects the amounts and characteristics of particulate species emitted from the raw materials in a glass melting furnace. To estimate the effect on particulate emissions from switching to fuel oil, the New Jersey Bureau of Air Pollution tested different types of industrial direct-fired combustion sources other than glass furnaces.[62] The emission factor for incremental particulate emissions generated by the combustion of number 2 fuel oil, as determined by this study, corresponds to 10-percent of the particulate emissions arising from the manufacture of soda-lime glass in uncontrolled, natural gas-fired furnaces, as shown in Table 3-4 (furnace systems without add-on control equipment are termed uncontrolled). The incremental particulate emissions from numbers 4, 5, and 6 fuel oil correspond to 15-percent of the soda-lime particualte emissions listed in Table 3-4. Recent emission tests on uncontrolled, soda-lime glass melting furnaces substantiate the roughly 10-percent increase in particulate levels from fuel oil-fired furnaces over the emissions from natural gas-fired furnaces.[63] For borosilicate glasses, although only one of these emission tests compares fuel oil and natural gas particulate emission levels, the emissions from fuel oil-fired furnaces are 10-percent more than the natural gas emissions.[64] In addition, these recent tests show that the characteristic size distribution of the particles evolved in glass melting furnaces remains independent of the type of fuel combusted.

The chemical nature of some pollutants does change if sulfur is present in the fuel. In the manufacture of lead glass when natural gas is burned, lead oxide is formed; when fuel oil containing sulfur is burned, this particulate is converted stoichiometrically to lead sulfate.[65]

3.2.2.3 Emissions From Forming and Finishing Operations

The final steps of glassmaking are termed "forming and finishing" and, depending on the final product, may include combinations of the following operations: forming by pressing, by blowing, or by both; surface treatment by metal chlorides to improve glass strength; annealing to remove internal stresses; decorating, dipping, or spraying a phenolic resin onto glass fibers. The nature of the pollutants released to the atmosphere from these steps invariably exist as gaseous emissions.[66,67,68]

Emissions have been tabulated in documents covering every glass industry segment, but reflect fewer emission tests than do emission factors for glass melting. Emissions have been determined for hydrocarbons, oxides of nitrogen, oxides of sulfur, metal oxides, metal chlorides, hydrogen fluoride, ammonia, and particualtes.[66,67,68] Despite the imprecision of these values, the emission factors are less by two orders of magnitude than those of glass melting furnace emissions. As is the case with emissions from raw material handling, these forming and finishing emissions will not be discussed further in this document.

3.2.2.4 State Emission Compliance Regulations

Table 3-5 lists particulate compliance limits for various glass production rates as allowed by states in which most of the glass manufacturing facilities are located. The table entries are calculated for existing Container Glass furnaces assuming that 85 percent of process weight rate is transformed into glass production, which corresponds to the normal 15 to 20 percent cullet usage.

The limits of Illinois,[69] Indiana,[70] New York,[71] Ohio,[72] Oklahoma,[73] and Texas[74] are formulated on a mass basis with an exponential dependence on process weight. California limits are represented by the allowable particulate emissions of the South Coast Air Quality Management District.[75] The New Jersey regulation for glass plants is also determined on a mass basis but with a linear dependence on process weight and with allowances made for increased cullet utilization.[76] The New Jersey Department of Environmental Protection makes an exception to the process weight limits for the case of furnaces producing lead glass where a compliance schedule of 0.02 Gr/SCF applies. West Virginia compliance regulations are interpolated from a table based on process weight.[77] Pennsylvania maintains a concentration basis regulation for Flat and Container Glass and mass basis regulation for Pressed, Blown, or Spun Glass.[78]

Table 3-5. STATE PARTICULATE REGULATIONS FOR EXISTING STATIONARY SOURCES

Pull Rate Tons/Day	Pull Rate Tons/Hr	Process Weight Tons/Hr	Indiana, Ohio Oklahoma, and Illinois		Texas		California South Coast Air Quality Management District		New Jersey		New York		West Virginia	
			kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)	kg/hr	(lb/hr)
24	1	1.2	2.1	(4.6)	1.7	(3.7)	1.8	(4.0)	2.5	(5.5)	1.9	(4.2)	1.1	(2.4)
50	2.1	2.5	3.4	(7.5)	3.4	(7.5)	2.5	(5.5)	2.8	(6.1)	3.1	(6.8)	2.2	(4.9)
75	3.1	3.7	4.5	(9.8)	5.1	(11.2)	3.1	(6.7)	3.0	(6.6)	4.1	(8.9)	3.4	(7.4)
100	4.2	4.9	5.4	(11.9)	6.8	(14.9)	3.8	(8.4)	3.3	(7.2)	4.9	(10.8)	3.8	(8.3)
150	6.3	7.4	7.1	(15.6)	10.1	(22.3)	4.3	(9.5)	3.8	(8.3)	6.4	(14.2)	5.8	(12.8)
200	8.3	9.8	8.6	(18.9)	13.4	(29.5)	5.0	(10.9)	4.3	(9.4)	7.8	(17.2)	7.2	(15.8)
250	10.4	12.3	10.0	(22.0)	16.7	(36.8)	5.4	(11.8)	4.8	(10.5)	9.0	(19.9)	7.5	(16.5)
300	12.5	14.3	11.3	(24.8)	20.0	(44.0)	5.8	(12.8)	5.3	(11.6)	10.2	(22.5)	8.6	(19.0)

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4.0 EMISSION CONTROL TECHNIQUES

4.1 INTRODUCTION

As identified in Chapter 3.0 of this document, emissions of nitric oxides, particulates, and sulfur oxides comprise the largest weight of pollutants released to the atmosphere by the uncontrolled manufacture of glass products. Examination of the emissions of these key pollutants for the three major operations of glass manufacturing, namely, raw material handling, glass melting, and forming and finishing, shows that essentially 100 percent of the oxides of nitrogen, 98 percent of the particulate, and essentially all of the oxides of sulfur are generated in the melting of glass. Because emissions are centered in the glass melting operations, the emission control techniques described in this chapter deal with the reduction of airborne emissions in the furnace exhaust. In addition to the previously mentioned major pollutants, which are emitted from all fossil-fuel fired glass melting furnaces, other pollutants emitted only from the production of special glass formulations pose potential health problems. These pollutants are: fluorine, lead, and arsenic.

As broadly applied in the glass industry, manufacturing methods termed "process modifications" lower glass melting furnace emissions either by altering raw material recipes or by modifying furnace equipment. In contrast to this definition, add-on control equipment refers to devices which treat only the glass melting furnace gaseous exhaust. In the next section of this chapter process modifications are discussed; all-electric melters are described in Section 4.3; in the following three sections add-on control techniques are described; in the last sections the control techniques are summarized and the reduction of arsenic, lead, fluorine, and sulfur oxide emissions are discussed. For each glass furnace test, the values of pertinent manufacturing rates and control system parameters are listed in this chapter. No additional discussions of the tests are made elsewhere in this document.

In general, two stack sampling methods have been used to measure particulate levels in the stack gases from glass melting furnaces. Both methods ensure that the sample withdrawn from the stack accurately represents the stack exhaust. Both methods use the same sampling equipment — a stack probe, a filter, and a set of impingers maintained at a temperature of 0°C (32°F). The basic difference between the two methods is the configuration of the sampling equipment. In one method, called the EPA Method 5,[1] the filter is maintained at about 120°C (250°F) and is placed upstream of the impingers. In the other method, developed by the Los Angeles Air Pollution Control District,[2] the impingers are placed upstream of the filter. The calculation of particulate emissions in the EPA Method 5 involves determining the dry weight of particulates captured in the probe and in the filter. In the Los Angeles method, the increase in weight of the impingers is measured by evaporating the impinger solutions, and this dry weight is included with the dry weights of particles captured in the probe and filter to determine the particulate emissions.

The EPA Method 5 has become the standard method for analyzing particulate emissions and is used as the basis of emissions in this document. Although no study has compared results of these methods on the same furnace exhaust, knowing the chemical composition of glass particulate emissions, comparisons can be projected. It is expected that the Los Angeles sampling configuration should not affect the particulate catch to any extreme. Additionally, the Los Angeles testing method should calculate slightly higher particulate emission levels than the EPA Method 5.[3]

4.2 PROCESS MODIFICATIONS

4.2.1 BATCH FORMULATION ALTERATIONS

Process modifications employed in the manufacturing of glass in order to lower emissions include: reducing the amounts of materials in the feed which vaporize at furnace temperatures; increasing the fraction of recycled glass in the furnace feed; installing sensing and controlling equipment on the furnace; modifying the burner design and firing pattern; and, utilizing electric boosting. The applicability of electric boosting for lower glass melting furnace emissions is discussed in the following subsection. Some process modifications offer the double benefits of lowering pollutant emission rates as well as lowering fossil fuel consumption rates.

Because emission tests are not available to document the lowering of particulate emissions by using process modifications, the evidence substantiating the efficacy of these methods is not as quantitative as is that for the other control strategies discussed later in this chapter. Nevertheless, these control methods and the approach to particulate emission control warrant consideration.

One of the principles used by glass manufacturers to lower emissions is straightforward. It involves the alteration of raw material recipes to lower or eliminate volatile constituents in the feed to the furnaces. Significant among compounds which have been removed from the feed in container glass manufacture is arsenic.[4] Feed rates of soda, fluorides, and selenium have been minimized. Since glass formulations fall in the area of proprietary information, no emission tests were obtained that show the decrease of emissions concomitant with the decreases of volatile compounds. The amounts of volatile raw batch materials may be decreased until one of two general types of lower constraints is reached. One lower limit is prescribed by the glassmaking process itself. An example of this type is soda, whose batch levels may be reduced until the glass product quality falls below production criteria. The other limitation on some batch constituents may be glass product specifications. Two examples of this sort are: the governmental regulations requiring minimum levels of lead and arsenic in television tubes;[5] and, the military specifications for textile fiberglass.[6]

Another alteration of raw material recipes which affects pollutant emissions involves increasing the levels of recycled glass in the raw batch mix. Since this recycled glass does not require heat to react, the furnace may be maintained at a lower temperature than that needed for a smaller cullet mix fraction. The lower temperature reduces the amounts of pollutants generated in the combustion of fossil fuel and the compounds vaporized from the glass bed. Once again, no emission test data are available to substantiate these results quantitatively. Normal cullet fractions in container glass range from 15 to 20 percent.[7] For some specialty glasses, the mass fraction of cullet in the feed may increase to about 70 percent. Glass manufacturers claim that cullet may be used only up to the level at which impurities in the cullet deleteriously affect glass product quality.

4.2.2 ELECTRIC BOOSTING

Electric boosting is the term applied to the technique of dissipating electrical current through molten glass. Electrical energy is converted to heat because of the high electrical resistance of the molten glass. For a fixed furnace throughput, utilizing electric boosting decreases the required bridgewall temperature, decreasing the fuel consumption rate, and thereby decreasing both particulate and gaseous pollutant levels. Boosting has normally been used to increase production rate since it does not require substantial modifications of the glass furnace. Boosting is commonly employed in container glass plants and is less commonly found in other types of glass plants.

In general, documentation of the lowering of emissions by electric boosting has not been available in the format of EPA Method 5 emission testing. For one natural gas-fired container glass furnace using electric boosting the particulate emissions per kilogram of glass produced dropped 55 percent from the uncontrolled level (the boosting electrodes supplied 18 percent of the total energy consumed in the furnace, despite a 12 percent increase in glass production rate). Emissions of SO_2 did not decrease when boosting was used.[8] Although information on the percentage of the total energy supplied by electric boosting was not available, it was determined that, on a rough basis, electric boosting provided less energy for this furnace than for the first furnace.

4.2.3 SUMMARY OF PARTICULATE EMISSIONS WITH PROCESS MODIFICATIONS

To assess the levels of particulate emissions from glass melting furnaces using process modifications including electric boosting, the particulate emissions prorated on the basis of glass production were determined for the furnace discussed in Section 4.2.2 and for furnaces identified by the Glass Packaging Institute as practicing most types of furnace and process control techniques.[10] For all these electrically boosted furnaces the particulate emission values range from 0.34 to 0.88 g/kg (0.68 to 1.76 lb/ton).[11,12] Although some of these emission tests do not match rigorous EPA Method 5 procedures, they are adequate enough to indicate rough levels of emissions.

Because of the narrow extent of these data and because of the lack of ample supporting emission tests, these values only exemplify the range to which particulate emission levels can be reduced by process modifications, including electric boosting. As such, they overlap with the emission levels indicated in Tables 3-5 and 3-6 and show that, in general, levels of particulate emissions from glass melting furnaces using process modifications are indistinguishable from the uncontrolled cases discussed in Chapter 3.0.

4.3 ALL-ELECTRIC MELTERS

In contrast to conventional fuel-fired furnaces, the surface of the melter in a cold top electric furnace is maintained at ambient temperature, and fresh raw batch materials are fed continuously over the entire surface. As molten glass is withdrawn from the melter, raw batch drops in the melter gradually heating and finally reacting in the liquid phase. This processing minimizes losses from vaporization. The gases discharged through the batch crust consist of carbon dioxide and water vapor.

Design objectives for all-electric melters have not been based primarily on emission control, but rather on efficient melting and product control. Construction is less expensive than that for fossil fuel furnaces since there are no regenerator chambers, port necks, checkers, flues, or reversing valves, and in most cases, stacks can be eliminated. Additionally, there is no need for ductwork, combustion blowers, fans, extra piping, burners, or special refractory shapes.

Accomplishment of design objectives resulted in a low surface temperature and a finer control on the glass melt formulation and therefore, small levels of emissions. The exact level of emission control capability is not soundly documented since some electric melting units employ no exhaust stacks and are vented openly inside the plant building. However, from the nature of the melting process, potential emissions can be deduced and possible relative amounts of emissions can be estimated. Since there is no combustion taking place, fuel-derived pollutants are eliminated. The only air emissions emitted are from the decomposition of carbonates, sulfates, and nitrates, with the majority of the exhausts being CO_2. Finer control of the glass melting process has meant lower emissions since electric melters retain more borates, phosphates, and fluorides than fossil fuel burning furnaces.[13] In addition, there is no solid disposal problem as with fabric filters or with electrostatic precipitators and no water disposal problem as with scrubber systems.

The development of all-electric melters has occurred relatively recently. All-electric melting technology has several key limitations which, at present, hinder the application of this technique throughout the glass industry. Not all glasses possess the electrical properties required for successful all-electric melter operation; other glass formulations attack the electrodes presently used in all-electric melters.[14] Additionally, the all-electric technology may not be far enough advanced to satisfactorily produce glass in large capacities.

Actual emission test results from all-electric furnaces are presented in Table 4-1. Little operational information was available on the melters except that they were maintained at normal operating conditions during the emission tests. The borosilicate glass melters were tested in accordance with the EPA Method 5 procedure; the soda-lime melter, although not using EPA Method 5, used an EPA approved sampling procedure with results including both condensed and filtered particulate. The particulate emissions from both glass formulations were equal in magnitude and ranged from 0.05 to 0.12 g/kg (0.1 to 0.24 lb/ton) based on the type of glass produced. These tests only partly indicate the potentially achievable emission control since only some all-electric melters have installed the exhaust stacks required for emission sampling. In visits to glass manufacturing facilities, all-electric melters were observed to discharge into the plant building. At these installations no visible emissions were detected and neither

Table 4-1. ALL ELECTRIC GLASS MELTING FURNACE PARTICULATE EMISSIONS TESTS

Emission Test Reference Number[a]	Glass Industry Category	Glass Type	All-Electric Furnace Particulate Emissions			
			Mass Emission		Particulate Concentration Corrected to 12 Percent Excess Oxygen[d]	
			g/kg	(lb/ton)	$Kg/nm^3 \times 10^{-4}$[b]	(Gr/DSCF)[c]
16	Wool Fiberglass	Soda-Lime Borosilicate	0.05	(0.10)		
17	Wool Fiberglass	Soda-Lime Borosilicate	.07	(.14)		
18	Wool Fiberglass	Soda-Lime Borosilicate	.09	(.18)		
19	Glass Container	Soda-Lime	.12	(.24)	9.6	(0.39)

[a] References are listed at the end of the chapter.

[b] Kilograms per normal cubic meter at 0°C and 760 mm. Hg.

[c] Gr/DSCF at 70°F and 1 atmosphere

[d] Gr/DSCF at 12 percent excess oxygen is calculated by the following formula:

Gr/DSCF at 12 percent oxygen = (Gr/DSCF at test conditions) $\left(\frac{9}{21\text{-measured } O_2 \text{ percent}}\right)$

fluoride nor sulfur odors were detected.[15] Based on these assumptions, the results from the emission tests represent relatively high levels of particulate emitted from all-electric melters.

In summary, all-electric melting has demonstrated that particulate emission levels equivalent to or less than 0.1 g/kg (0.2 lb/ton) can be maintained in the production of soda-lime and borosilicate glasses. Comparison of all-electric melters with other control techniques is made in Section 4.8.

4.4 CONVENTIONAL FABRIC FILTER SYSTEMS

Several glass manufacturing facilities utilize fabric filter systems to collect particulates in the glass melting furnace exhaust. In these systems, the furnace exhaust is first cooled and then passed through a fabric filter which retains particulate, and allows the gases to vent to the atmosphere. The physical characteristics of the filtering fabrics and the agglomerating tendency of submicron particles have made the fabric filter systems viable control techniques for the collection of glass melting furnace particulates.

Figure 4-1 illustrates a typical baghouse system. In operation, a fan pulls the furnace gases through devices which cool the gases to a temperature compatible with the filter material. Cooling is accomplished by duct cooling, dilution air addition, or water injection. The gases are then forced through the filter bags. Periodic cleaning of the bags is necessary to maintain high collection efficiencies. Filter bags are cleaned through shaking or reverse air pulsations. Conveyors transfer the collected dusts to hoppers for disposal.

Fabric filter systems are claimed to have the advantages of: high collection efficiency (99 percent);[20] low pressure drop across the system; and, low energy requirements.[21] Collection efficiencies are not affected by the electrical resistivity of the particles.

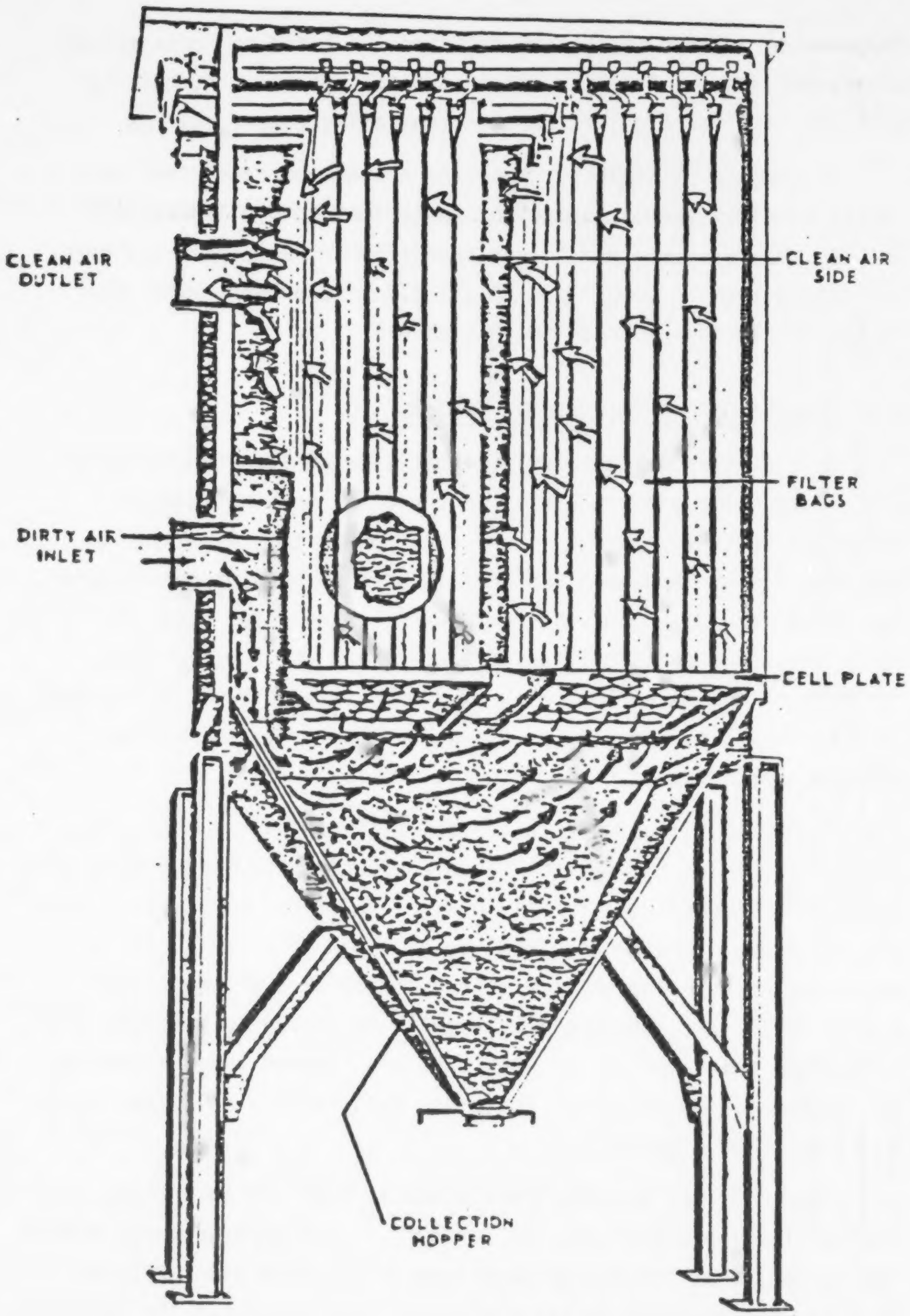

CLEAN AIR OUTLET
CLEAN AIR SIDE
FILTER BAGS
DIRTY AIR INLET
CELL PLATE
COLLECTION HOPPER

Figure 4-1. A Simple Two Cell Inside Out Baghouse Equipped for Shake Cleaning[23]

In addition, bag life is about two years depending on the bag construction material.[22] There are certain disadvantages to the application of fabric filters to glass melting furnace gases: the temperature of gases entering the fabric filter must be below a maximum value to inhibit attack on the filtering media as well as above a minimum value to prevent condensation of sulfur trioxides; and, too high a moisture content of the gases can form an irremovable plug within a filter bag.

Table 4-2 lists emission test results for furnaces using baghouse systems. The following summarizes testing parameters and irregularities encountered for each test.

Test 24 results are from a natural gas-fired soda-lime glass melting regenerative furnace. The Los Angeles approved particulate sampling configuration emission test was used. The fabric filter system consists of six modules entailing a total bag surface area of 1,204 m^2 (12,960 ft^2). The design a/c ratio is 1:1 but during testing the a/c ratio was about 0.65:1. The pressure drop across the system is normally 1,250 to 1,500 Pascals (Pa), which is equivalent to 5 to 6 inches of water.

Central to the interpretation of this test data is the design basis of this fabric filter system. The unit was designed only to meet local opacity regulations. Since the unit met the regulations after startup, no improvement of particulate collection was attempted.

In operation the system incurred mechanical failures in the first year of operation but slight modifications to the fabric filter internals eliminated the difficulties. Also, the original onstream cleaning method used reverse air blown between the bags to collapse the inner bag, cleaning the bag without taking a section offstream. This original method was modified to the present arrangement of a reverse air cleaning cycle where a baghouse section is taken offstream, with the double bag construction being retained.

Table 4-2. PARTICULATE EMISSION TEST RESULTS FOR GLASS MELTING FURNACES EQUIPPED WITH FABRIC FILTERS

Emission Test Reference Number[a]	Glass Industry Category	Glass Type	Air/ Cloth Ratio	Particulate Removal Efficiency Percent	Fabric Filter Outlet Particulate Emissions			
					Mass Emissions		Particulate Concentration Corrected to 12% Excess Oxygen	
					g/kg	(lb/ton)	kg/Nm^3 x 10^{-4}	(gr/DSCF)
24	Pressed and Blown: Soda-lime	Soda-lime	0.65 : 1	72	0.12	(0.24)	0.26	(0.011)
25	Pressed and Blown: Other than soda-lime	Soda-lead-borosilicate	0.6 : 1	94.8	.17	(.34)	.22	(.009)
26	Wool Fiberglass	Borosilicate	0.85 : 1		.2	(.4)	.36	(.015)
27	Wool fiberglass	Soda-lime-borosilicate	0.5 : 1		.55	(1.1)	-	(.059)[b]
28	Wool fiberglass	Soda-lime-borosilicate	-		.26	(.52)	-	(.02)[b]

[a] References are listed at the end of the chapter.

[b] Not corrected to 12 percent oxygen

[c] Fuel Oil

The results for emission test 25 were measured on a glass melting regenerative furnace burning low sulfur number 5 fuel oil and producing soda-lead borosilicate glass, a specialty glass classified in the Pressed and Blown category of manufacturing. Emission tests using EPA Method 5 were made on the furnace exhaust before and past the fabric filter allowing the calculation of the particulate removal efficiency. The design value of the air-to-cloth ratio (a/c) is 0.6:1 with all four modules exposed to furnace exhaust and is 0.8:1 with three modules exposed to the furnace gases and one module being cleaned. In addition, no operational difficulties with this fabric filter system were reported.

Data listed for emission test 26 are the preliminary results of an EPA Method 5 test recently performed on a natural gas-fired glass melting furnace producing wool fiberglass. This fabric filter is considered undersized by the glass manufacturer.

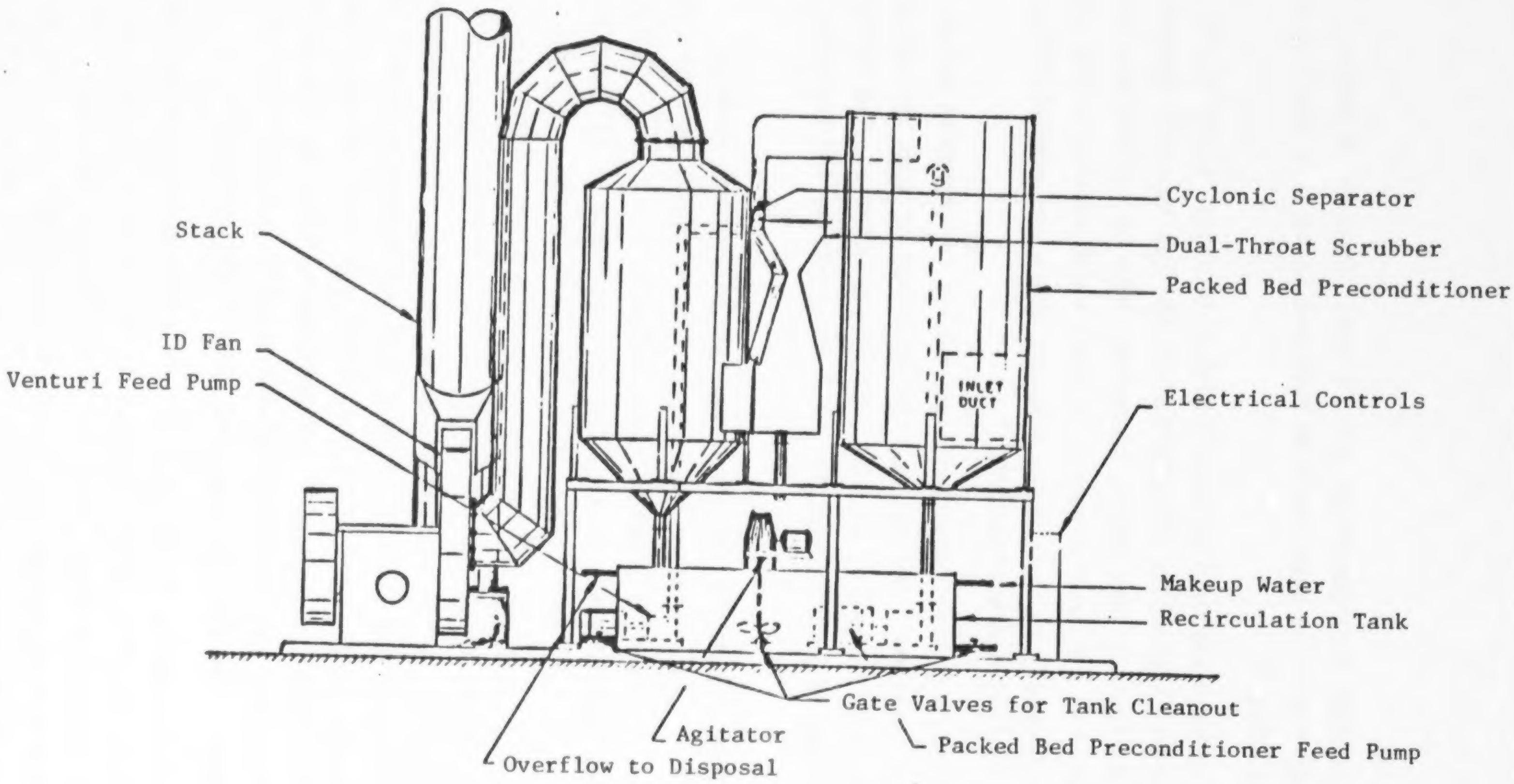
Emission tests 27 and 28 report particulate emissions as calculated by the front-half and back-half catches for the EPA Method 5 sampling configuration. Therefore, these results are higher than the Method 5 particulate determinations. The glass formulation melted in these furnaces is soda-lime borosilicate producing an end-product classified in the Wool Fiberglass industry category. The furnace of test 27 is a regenerative type. The fabric filter in test 28 controls emissions from a small recuperative-type furnace, a raw material batch house, and an electric-melt-gas-boosted furnace. Particulate concentrations in the fabric filter discharge are not corrected to 12 percent oxygen as the oxygen concentrations during the tests were not available.

Particulate emissions for the tests listed in Table 4-2 range from 0.12 g/kg (.24 lb/ton) to 0.55 g/kg (1.1 lb/ton). The high collection efficiency claimed for fabric filters is substantiated in the soda-lead borosilicate glass test. As mentioned before, the particulate collection efficiency of the fabric filter treating the soda-lime furnace exhaust may be lower than the efficiency which is technically feasible because particulate collection was never maximized in this system. In conclusion, fabric filters have demonstrated reductions of particulate emissions to levels equivalent to less than 0.2 g/kg (0.4 lb/ton) for glass formulations in two glass industry categories: Wool Fiberglass and Pressed and Blown: other than soda-lime. Additionally, based on the assessment of test 24, appropriately sized and optimized fabric filter systems can be expected to reduce particulate emissions from soda-lime melting furnaces to levels of 0.1 g/kg (0.2 lb/ton).

4.5 VENTURI SCRUBBER SYSTEMS

Although scrubber systems have been built to control particulate emissions in the glass industry, presently only a few devices are in use controlling container glass emissions. The most common system in operation is the venturi scrubber. A typical venturi scrubber is depicted in Figure 4-2. In a venturi scrubber, particle-laden gases are accelerated through a restriction in the ducting where water is injected into the gas stream. The velocity of the gas stream provides the dual function of atomizing the scrubbing fluid while at the same time providing a differential velocity between particles and the resulting liquid droplets. By utilizing high power fans to accelerate the gas stream, it is possible to generate high gas velocities at the throat of the venturi. Since the particulates are mostly water soluble, the scrubber provides a means of removing these emissions. Additionally, some gases are absorbed as condensables.

The scrubber liquor is acidic due to the absorbed acid gases, and, before being recycled to the venturi, is pH controlled by caustic solution injection. A bleed stream and makeup water addition insure that the scrubber liquor is not saturated. Typically, a bleed rate of 1.3×10^{-4} m^3/s (2 GPM) is discharged for a


Stack
ID Fan
Venturi Feed Pump
Cyclonic Separator
Dual-Throat Scrubber
Packed Bed Preconditioner
INLET DUCT
Electrical Controls
Makeup Water
Recirculation Tank
Gate Valves for Tank Cleanout
Agitator
Packed Bed Preconditioner Feed Pump
Overflow to Disposal

Courtesy of FMC Corporation

Figure 4-2. Typical Scrubber System

2.1 kg/s (200 TPD) container glass plant. Even for a larger furnace, the bleed rate would be expected to be less than 3.2×10^{-4} m^3/s (5 GPM).[29]

The pressure drop to obtain high velocities in the throat of a scrubber is directly proportional to the gas velocity squared and the liquid to gas ratio; therefore, high velocities are possible only at substantial pressure drops which result in high fan energy expenditures. Typical pressure drops are approximately 7,500 Pa (30 inches of water).[30]

Table 4-3 lists emission test results for furnaces using scrubber systems. Due to the limited number of such systems used in the glass industry, limited data were available. The following summarizes testing parameters and irregularities for the available data.

Test 31 results are for a dual throat venturi scrubber installed on a container glass furnace burning 0.5 percent sulfur fuel oil. The liquid water-to-gas ratio is 3.9×10^{-3} $[m^3/s]/[m^3/s]$ (0.0029 GPM/SCFM) for this system with an 8,212 Pa (33 inches of water) pressure drop. There is an estimated 0.0053 kg/s (42 lb/hr) of Na_2SO_4 dissolved in the water discharge which is diluted by plant cooling water and discharged without further treatment. Although the system was not designed for SO_2 control, approximately 90 percent of the SO_2 was removed from the furnace exhaust. This system has experienced startup problems and after startup, two major maintenance problems: the replacement of a fan due to lining failure; and, the rebuilding of a hydraulic reservoir tank due to collapse. The testing method is that of EPA Method 5.

Test results 32 and 34 are from a packed-bed preconditioning chamber, variable throat scrubber installed on a natural gas-fired glass melting furnace. Test 32 is an emission test using the Los Angeles testing method and Test 34 uses EPA Method 5. The design liquid to gas ratio is $2.3 \times 10^{-3}[m^3/s]/[m^3/s]$ (0.0017 GPM/SCFM)

Table 4-3. PARTICULATE EMISSION TEST RESULTS FOR GLASS MELTING FURNACES EQUIPPED WITH VENTURI-SCRUBBERS

Emission Test Reference Number[a]	Glass Industry Category	Glass Type	Particulate Removal Efficiency Percent	Venturi-scrubber Outlet Particulate Emissions			
				Mass Emissions		Particulate Emissions Corrected to 12% Excess Oxygen	
				g/kg	(lb/ton)	kg/Nm^3 x 10^{-4}	(gr/DSCF)
31[b]	Container	Soda-lime	82.5	0.37	(0.74)	-	(0.042)[c]
32	Container	Soda-lime		.12	(.24)	.38	(.016)
33[b]	Container	Soda-lime	79.6	.14	(.28)	.40	(.016)
34	Container	Soda-lime		.20	(.40)	.56	(.023)

[a] References are listed at the end of the chapter.

[b] Oil-fired

[c] Not corrected to 12 percent excess oxygen

with a 7,500 Pa (30-inch water) pressure drop. The liquid effluent is released directly to the sewer. Also, a weak alkaline solution, which is recirculated through the packed tower and venturi scrubber, is used to scrub SO_2 and particulates from the gases. The design calls for 0.0011 m^3/s (16.8 GPM) of makeup water, 9.64×10^{-7} m^3/s (22 GPD) of 50 percent caustic and produces a waste liquid stream of 8.2×10^{-4} m^3/s (1.3 GPM), containing 1 to 2 percent dissolved solids and 1 to 2 kg/m^3 (1,000 to 2,000 ppm) suspended solids. There has been no major equipment failure to date; no plugging has been experienced; and, no problems with corrosion have arisen. A number of minor operating difficulties have been encountered, almost all relating to the instrumentation system. In addition to the particulate reduction, there was a 75 percent reduction in sulfur oxides with a 7 ppm SO_2 system discharge.

Test 33 results are from a packed-bed preconditioning chamber, dual throat scrubber using the EPA Method 5 testing procedure for an oil-fired container glass furnace. The liquid-to-gas ratio is $9.4 \times 10^{-3} [m^3/s]/[m^3/s]$ (0.07 GPM/SCFM) estimated from design conditions with an 8,500 Pa (34-inch water) pressure drop. There is a $6.3 \times 10^{-4} m^3/s$ to $9.5 \times 10^{-4} m^3/s$ (10 to 15 GPM) bleed rate which is discharged directly to the sanitary sewer. This system has experienced a problem with the scrubber exhaust fan which caused the system to be shut down. During the three months of operation, it was necessary to twice clean the impeller blades and fan housing in order to eliminate an imbalance. Also, there were problems with the pH control system, the soda ash solution mixing apparatus, and other minor items. The system has been operating continuously for three months. Operational and maintenance problems are still being analyzed. In addition to particulate reduction, sulfur oxides were reduced 86.3 percent with a 100 ppm discharge concentration.

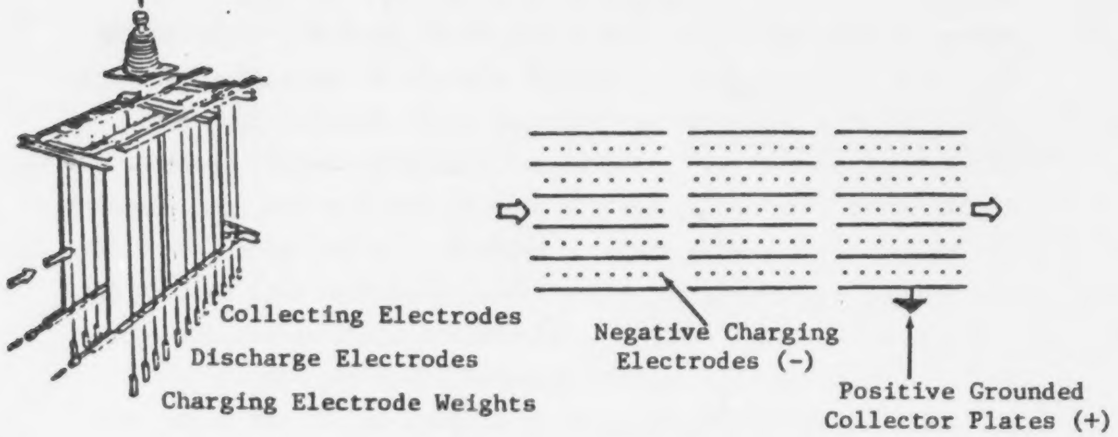
Table 4-3 lists particualte emission tests for venturi scrubbers installed on container glass melting furnaces. Test number 33 reports results for an oil-fired furnace. Although the pull rate for this test was only 57 percent of the maximum furnace capacity, this test data was included as it substantiates the particulate control efficiencies achievable by venturi scrubbers. As discussed previously, tests 32 and 34 are from the same furnace but represent different sampling methods. The emissions per kilogram of glass produced for these tests range from 0.12 to 0.20 g/kg (0.24 to 0.4 lb/ton). These tests demonstrate that venturi scrubbers can lower the particulate emissions from uncontrolled container glass melting furnaces to a level equivalent to or less than 0.20 g/kg (0.4 lb/ton). A comparison of scrubber systems with other control techniques is discussed in Section 4.8.

4.6 ELECTROSTATIC PRECIPITATORS

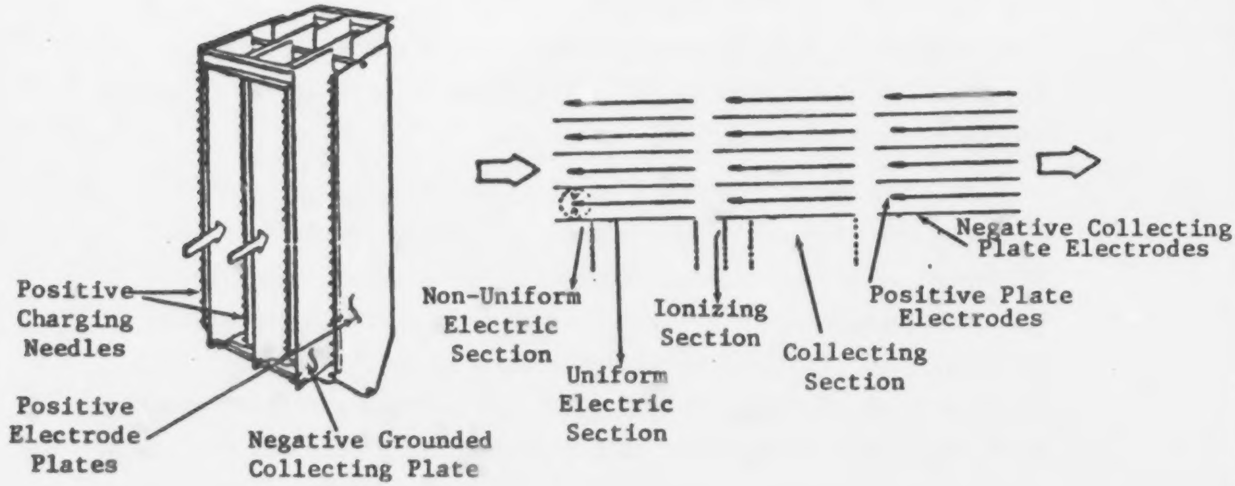
Presently, more than 19 electrostatic precipitators are installed on glass furnace exhaust systems throughout the country, (more than any other control technique).

The fundamental steps of electrostatic precipitation are particle charging, collection, and removal and disposal of the collected material. Particulate charging is accomplished by generating charge carriers which are driven to the particulates by an electric field. Collection occurs as the charged particulates migrate to electrodes to which the charged particles adhere. Applying a mechanical force to the collection electrodes dislodges the collected material which then falls into hoppers. Effective transfer of dust to the hopper depends on the formation of chunks or agglomerations of dust which fall with a minimum of reentrainment.

There are two types of electrostatic presipitators used in the glass industry. Both types are shown in Figure 4-3. One type consists of a large rectangular chamber divided by a number


Collecting Electrodes
Discharge Electrodes
Charging Electrode Weights
Negative Charging Electrodes (-)
Positive Grounded Collector Plates (+)

Conventional Electrostatic Precipitator


Positive Charging Needles
Positive Electrode Plates
Negative Grounded Collecting Plate
Non-Uniform Electric Section
Uniform Electric Section
Ionizing Section
Collecting Section
Positive Plate Electrodes
Negative Collecting Plate Electrodes

NAFCO Electrostatic Precipitator

Figure 4-3. Conventional and NAFCO Electrostatic Precipitators[35]

of parallel rows of collection plates that form gas flow ducts. Between these plates are hung a number of small diameter wires which are connected to a high voltage direct current potential forming a corona discharge around the wire. This corona generates electrons which migrate into the incoming gas stream to form gas ions which attach these charged particles. The charged particles, in turn, are collected by the grounded collection plates.

The other type of ESP has a multitude of stainless steel needles fastened to the leading and trailing edge of the discharge plates. This design configuration requires a low voltage which allows close spacing between the two collecting surfaces in each field: the positively charged discharge plates, which have the attached needles; and, the grounded collector plates. This close plate spacing permits short collecting sections and relatively high flow-through velocities.[35] Additionally, the regions between the needles exhibit a uniform electric field which aids particle agglomeration. Dust is retained on both the collector plates and discharge plates.

Electrostatic precipitators can be designed and guaranteed to collect 99 percent of the particulate in the glass melting furnace exhaust.[36] Resistivity of the particulate is a determining design parameter. If the particulate cannot conduct the ionic current from the corona discharge, it will be entrained and will be released to the atmosphere. Resistivities are highly dependent upon temperature with a decrease in resistivity occurring with an increase in temperature. Some typical resistance figures for various types of glass are:[35]

Borosilicate glass	10^{12} ohm - cm
Lead glass	10^{11} ohm - cm
Soda-lime glass	10^{7} to 10^{10} ohm - cm (Depending on temperature and moisture content)[37]

Table 4-4 lists emission test results for electrostatic precipitator-controlled glass melting furnace exhaust. In some plant configurations one or more electrostatic precipitators collect particulates from several furnaces. In these cases the table entries list the total pull rates from all furnaces whose exhausts are controlled during testing and the sum of the particulate emissions of all electrostatic precipitators in the plant. The following are summaries of the testing parameters and irregularities experienced.

Test 38 results are from a test employing the Los Angeles testing procedure on a furnace producing soda-lime glass. No data were available for ESP operational parameters. The unit has been running successfully since startup.

Test 39 results are from a test employing the Los Angeles testing procedure on a soda-lime melting furnace. The design specific collection area of the unit is 138 $m^2/[Nm^3/s]$ (0.65 ft^2/SCFM), and during testing the unit was operating at about 83 percent of design SCGM. Natural gas was fired during testing. There have been generally satisfactory results with the operation of this unit.

Test 40 results, also on a soda-lime furnace, are from a test employing the EPA Method 5 procedure. The design specific collection area of the unit is 237 $m^2/[Nm^3/s]$ (1.12 ft^2/SCFM), and during testing the unit was operating at about 116 percent of design conditions.

Tests 41 through 44 report particulate emissions from borosilicate glass formulations melted in furnaces classified in the Pressed and Blown: other than soda-lime category.

Test 41 results are from a test employing the EPA Method 5 procedure. The design specific collection area of the unit is 225 $m^2/[Nm^3/s]$ (1.06 ft^2/SCFM), and during testing the unit was

Table 4-4. PARTICULATE EMISSION TEST RESULTS FOR GLASS MELTING FURNACES EQUIPPED WITH ELECTROSTATIC PRECIPITATORS

Emission Test Reference Number[a]	Glass Industry Category	Glass Type	Specific Collection Area		Percent of Design SCFM During Test	Particulate Removal Efficiency %	Precipitator Outlet Particulate Emissions			
							Mass Emissions		Particulate Concentration Corrected to 12% Excess Oxygen	
			$m^2/(Nm^3/s)$	$(Ft^2/SCFM)$			g/kg	(lb/ton)	$kg/Nm^3 \times 10^{-4}$	(Gr/DSCF)
38	Container	Soda-lime	b	b		91	0.06	(0.12)	0.14	(0.006)
39	Container	Soda-lime	138	(0.65)	83		.07	(.14)	.36	(.015)
40	Container	Soda-lime	237	(1.12)	116		.06	(.12)	.25	(.010)
41	Pressed and Blown: Other than Soda-lime	Borosilicate	225	(1.06)	100					
42	Pressed and Blown: Other than Soda-lime	Borosilicate	138	(0.65)	89		.57	(1.14)	1.37	(.056)
43	Pressed and Blown: Other than Soda-lime	Borosilicate	290	(1.37)	43		.48	(.96)	.18	(.007)
44	Pressed and Blown: Other than Soda-lime	Borosilicate	179	(.85)			.10	(.20		(.002)[c]
45	Pressed and Blown: Other than Soda-lime	Fluoride/ Opal	379	(1.79)	84		.17	(.34)	.32	(.012)
46	Pressed and Blown: Other than Soda-lime	Lead	233	(1.09)	75	98	.06	(.12)	.10	(.004)
47	Pressed and Blown: Other than Soda-lime	Lead	337	(1.59)	117		.08	(.16)	.12	(.005)[c]
48	Pressed and Blown: Other than Soda-lime	Lead					.08	(.16)	.15	(.006)
49	Pressed and Blown: Other than Soda-lime	Lead	183	(.86)	91		.07	(.14)	.06	(.002)
50	Pressed and Blown: Other than Soda-lime	Lead	195	(.92)	80		.18	(.36)		(.004)[c]
51	Pressed and Blown: Other than Soda-lime	Lead				97	.27	(.54)	.42	(.017)
52	Pressed and Blown: Other than Soda-lime	Potash-Soda-lead	237	(1.12)	122		.03	(.06)	.30	(.012)
53	Wool Fiberglass	Borosilicate	220	(1.04)			.36	(.72)	.64	(.026)
54	Wool Fiberglass	Borosilicate	222	(1.05)			.09	(.19)	.18	(.007)
55	Wool Fiberglass	Borosilicate	216	(1.02)			.09	(.17)	.12	(.005)

a. References are listed at the end of the chapter

b. Claimed proprietary

c. Not corrected to 12% excess oxygen

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operating at about design conditions. Natural gas was fired during the testing period. There have been no major problems encountered with this unit.

Test 42 results are from a test employing the EPA Method 5 procedure. The design specific collection area of the unit is 138 $m^2/[Nm^3/s]$ (0.65 $ft^2/SCFM$), and during testing the system was operating at about 89 percent of design SCFM. Natural gas was fired during testing. There are no available comments regarding operating problems.

Test 43 results are calculated using EPA Method 5. This electrostatic precipitator is sized for two glass melting furnaces, but only one furnace was operating during the test. The glass pull rate is calculated as 85 percent of the process rate. The manufacturer has encountered dust build-up on the blades of the fan used with this electrostatic precipitator.

Particulate emissions from test 44 are evaluated from the EPA Method 5 technique. Number 5 fuel oil was fired for this test. There are no other available comments regarding the operation of this precipitator or regarding difficulties encountered in its use.

Results listed for test 45 report particulate emissions for an electrostatic precipitator installed on a glass melting furnace producing fluoride-opal glass. Pull rate is assumed to be 85 percent of process weight rate. Natural gas was combusted during this test.

Tests 46 through 51 report particulate emissions from electrostatic precipitators installed on Pressed and Blown: other than soda-lime furnaces melting lead glass formulations.

EPA Method 5 was used to determine the particulate emissions for test 46. The design value of specific collection area is 233 $m^2/[Nm^3/s]$ (1.09 $ft^2/SCFM$); and during the test, the flow rate through the unit was 75 percent of the design value. The glass pull rate is calculated as 85 percent of the process weight rate. Problems arising in the application of this control device were: dust build-up on the blades of the exhaust fan, broken insulators, and arcing.

Test 47 results are from a test employing the EPA Method 5 procedure. The design specific collection area of the unit is 337 $m^2/[Nm^3/s]$ (1.59 ft^2/SCFM), and during testing the unit was operating at about 117 percent of design flow rate. Natural gas was fired during testing. There have been no major operational problems encountered.

In test 48, the particulate emissions are reported from an EPA Method 5 test. Natural gas was used during this test. Again, pull rate is assumed to equal 85 percent of process weight rate.

Test 49 lists particulate emissions for a natural gas-fired furnace using EPA Method 5. Pull rate is calculated as being 85 percent of the process weight rate. No additional comments are available about the unit.

Test 50 results are from a test employing the EPA Method 5 procedure. The design specific collection area of the unit is 195.07 $m^2/[Nm^3/s]$ (0.92 ft^2/SCFM), and during testing the unit was operating at about 80 percent design SCFM. Natural gas was used in the furnace during testing and there was no available information as to operating problems encountered with the device.

No other information is available on test 51 other than: the testing procedure followed, (EPA Method 5); the furnace fired natural gas; and, the data listed in Table 4-4.

Test 52 results are from a natural gas-fired furnace producing potash-soda-lead glass with emissions determined by a sampling train similar to the EPA Method 5 train with two exceptions: A Whatman filter was used and the filter temperature was not maintained at 250°C. The design specific collection area is 237 m^2/

[Nm^3/s] (1.12 ft^2/SCFM), and during testing the unit was operating at about 120 percent design flow rate. No data were available as to collection efficiency; the capture dust was analyzed as follows: 79.4 percent PbO, 1.66 percent As_2O_3, 5.33 percent As_2O_5. There have been no major operational problems with this unit.

Tests 53 through 55 report particulate emissions from wool fiberglass plants equipped with electrostatic precipitators. No other information or comments from the glass manufacturer are available other than those listed in Table 4-4.

The particulate emissions for soda-lime formulations produced in the Container Glass category and for the lead, fluoride-opal, and potash-soda-lead formulations produced in the Pressed and Blown: other than soda-lime category which are listed in Table 4-4 range from 0.3 g/kg to .27 g/kg (0.6 lb/ton to .54 lb/ton). These results include tests on both precipitator configurations illustrated in Figure 4-3. For borosilicate glass formulations manufactured in the Pressed and Blown: other than soda-lime category and in the Wool Fiberglass category, the particulate emission test results range from .09 g/kg to .57 g/kg (.17 to 1.14 lb/ton). Two factors could explain the higher emissions for borosilicate emissions despite the larger special collection area: the higher electrical resistivity of borosilicate dusts; and, the tendency for the collected dusts to bridge in the precipitator.[56] Since the resistivity of the lead dusts is nearly equal to the resistivity of borosilicate dusts and since the lead particulate is collectable, the second factor may control the collection of borosilicate glass melting furnace emissions.

In conclusion, electrostatic precipitators have demonstrated particulate emission control levels of 0.06 g/kg (.12 lb/ton) for soda-lime, lead, and potash-soda-lead glass formulations, and levels of about 0.2 g/kg (0.4 lb/ton) for borosilicate glass formulations. A comparison of electrostatic precipitators with other control techniques is discussed in Section 4.8.

4.7 ADDITIONAL AND DEVELOPING CONTROL TECHNIQUES

4.7.1 FABRIC FILTER WITH ADDITIVE INJECTION

This control technique utilizes the continuous injection of chromatographic solids to agglomerate submicron particulate and to absorb gaseous pollutants. These chromatographic solids are separated from the gas stream by a conventional fabric filter. The solids can either by recycled or disposed of in landfill. This dry system consists of the following equipment: a gas quench-humidification system, a metering additive injector, and a fabric filter. The typical pressure drop across the system is about 2,000 Pa (9 inches of water). The additive injection and fabric filter system has been tested on emissions from a furnace producing float glass (the most common type of flat glass), on fiberglass furnace emissions, and on container glass melting furnace emissions.

Although emission testing methods are not indicated for the float glass or fiberglass tests, particulate removal efficiencies are reported to be over 95 percent.[57] In emission tests of a container glass melting furnace using this system the particulate removal efficiency averaged 85 percent with a zero opacity visible outlet emission.[58] For all types of glass, the grain loadings are less than 0.12×10^{-4} kg/NM^3 (0.005 Gr/DSCF).

4.7.2 MIST ELIMINATORS

Mist eliminators, developed primarily for removing liquid mist emissions in the sulfuric acid industry, have been pilot tested on a slipstream of a natural gas-fired container glass melting furnace. The mist eliminators utilize impaction, interception, and Brownian movement to collect on irrigated fibers. Gases containing mist and spray particles pass through a fiber bed. The particles are then collected on the fibers in the bed and coalesce into liquid films. These films fall from the fiber bed by gravity and the liquid drains out through drain legs. The mist eliminator element consists of a cylindrical fiber bed with gas flow passing through the annular bed and out the center of the element. Gases emerge from the bed and rise to the system exit.

The results of particulate sampling with an Andersen particle fractionating sampler show a 96.4 percent collection efficiency of particulate smaller than 3 microns across the high efficiency element, but, due to condensation of nonsulfate compounds and reentrainment from the prefilter, the total system collection efficiency was found to be 93.6 percent.[59] The measured concentration of SO_2 and SO_3 vapor did not decrease through the system. Total pressure drop through the system was about 2,600 Pa (10.5 inches of water).

Because of the sampling method used and because of the preliminary state of the pilot application of the mist eliminator to glass melting furnace exhaust, no firm conclusion about the particulate removal efficiency can be made in this document.

4.8 SUMMARY OF PARTICULATE CONTROL TECHNIQUES

Table 4-5 assesses the levels of particulate emissions emitted from the control systems discussed in this chapter for each industrial glass category except flat glass manufacturing. The emission levels listed in Table 4-5 represent particulate control technically achievable as substantiated by test reports, and therefore, reflect the lower values from the previous tables.

All-electric melting of glass has been shown to be effective in greatly reducing the particulate emissions from glass melting furnaces without the addition of add-on control equipment. This technique is not applicable to the entire glass industry as, at present, only formulations of appropriate resistivity and furnaces of relatively moderate production rates can utilize all-electric melting.

Table 4-5. REPRESENTATIVE PARTICULATE EMISSIONS FROM GLASS MELTING FURNACES

Glass Industry Category	Glass Type	All-Electric Melting		Fabric Filter		Venturi Scrubber		Electrostatic Precipitator	
		g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)
Container	Soda-lime	.12	(.24)			.20	(.40)	.06	(.12)
Pressed and Blown: Soda-lime	Soda-lime			.12	(.24)				
Pressed and Blown: Other than Soda-lime	Lead							.08	(.16)
Pressed and Blown: Other than Soda-lime	Fluoride/ Opal							.17	(.34)
Pressed and Blown: Other than Soda-lime	Borosilicate			.17	(.34)			.50	(1.0)
Wool Fiberglass	Borosilicate	.07	(.14)	.25	(.50)			.10	(.20)

Fabric filters have been installed on existing furnaces classified in both the Pressed and Blown categories and in the Wool Fiberglass category. As mentioned previously, in the fabric filter system installed on the soda-lime formulation, particulate collection was never maximized, implying that the emissions could be lowered for this melted glass type.

Venturi scrubbers have been installed on existing container glass furnaces. Scrubbers have not been used to control borosilicate emissions because the chemicals discharged in the liquid effluent present more of a disposal problem than those from soda-lime glasses.[60]

Electrostatic precipitators have been installed widely in the glass manufacturing industry. Significant amounts of emission tests substantiate the values listed in the table.

Switching fuels from natural gas to fuel oil adds particulate formed in combustion to the particulate formed in producing glass. The add-on control devices discussed in this chapter would be expected to be equally efficient in controlling particulate emissions with either fuel. As demonstrated in Tables 4-3 and 4-4, venturi scrubbers and electrostatic precipitators have previously been used on fuel oil-fired glass melting furnaces.

Although, as of June 1978, no add-on control system continuously controls particulate emissions from a flat glass manufacturing furnace, there is no technical evidence to preclude their use. The flat glass furnaces produce more soda-lime glass than container furnaces, but the physical and chemical natures of the resulting particulate are identical. Because of the greater glass production in flat glass furnaces and concomitant larger exhaust volume than in container glass furnaces, an electrostatic precipitator would probably best control the particulate emissions. For this reason, and because one flat glass manufacturer is presently installing an electrostatic precipitator, these devices are listed as the regulatory options for the flat glass industrial category in Chapters 6.0 and 7.0.

4.9 CONTROL OF SULFUR OXIDES, FLUORIDE, ARSENIC, AND LEAD EMISSIONS FROM GLASS MANUFACTURING

Because sulfur oxides are present in gaseous form in glass melting furnace exhaust, their control requires a different approach than that of the control of particulate. One control technique, the wet scrubber, had demonstrated on commercial scale glass plants good control of both sulfur oxides and particulates, simultaneously. As documented in this chapter, 75 and 85 percent reductions of sulfur oxides were measured for two variable throat, venturi scrubber systems. The concentrations of sulfur oxide emissions, calculated as SO_2, from these facilities were 7 ppm and 100 ppm respectively.

Although one test on an electrostatic precipitator showed some sulfur oxide removal, in general, the other add-on control techniques discussed in this chapter do not reduce the levels of sulfur oxides unless other equipment is installed. The one test showed a 40 percent reduction of SO_3 and 15 percent reduction of SO_2 across an electrostatic precipitator.[61] This result has not been documented in other tests. Treating the exhaust stream with an alkaline spray has been claimed to convert the gaseous sulfur oxides to solids which can then be collected by a fabric filter or an electrostatic precipitator.

In addition, if sulfur oxides are not treated in the glass melting furnace exhaust when certain fuel oils are burned, they may lower the collection efficiencies of electrostatic precipitators. If the fuel oil contains vanadium, the reaction of sulfur trioxide to sulfuric acid will be catalyzed. This sulfur acid is not only corrosive to the metal internals of the precipitator but also makes the agglomerated particulate stick to the collector plates, lowering collection efficiencies.[62]

Fluorine used in several glass formulations classified in pressed and blown glass manufacturing may be emitted in both particulate and gaseous forms in the melting furnace exhaust. Tests on the uncontrolled glass melting furnace emissions show, on the average, that one half of the fluorine is present in the particulate catch and the other half is present in the impinger and therefore, exists as a gas in the exhaust.[63]

Not much analysis has been reported, but that which was available shows electric boosting reduces fluoride emissions by about 75 percent in particulate but increased the fluoride in gaseous form by 43 percent.[64] When the exhaust from an opal glass manufacturing furnace was treated with a lime slurry, 85 percent of the fluoride emissions were captured in an electrostatic precipitator.[65]

Little test data on arsenic emissions are available. One test shows that about 80 percent of the arsenic captured in an emission test was in particulate form.[66] Electrostatic precipitators have been shown to be 99.4 percent effective, and 42 percent effective in the capture of this particulate form of arsenic.[67]

Electrostatic precipitators have been shown, in two tests, to collect 70 percent, and more than 90 percent of the lead particulate in glass melting furnace exhaust.[68]

4.10 REFERENCES FOR CHAPTER 4.0

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2. Los Angeles County Air Pollution Control District, Air Pollution Source Testing Manual, Chapter 4, 1972.

3. Memo from D. Bivens, EMB, to W.O. Herring, ISB, October 28, 1977.

4. Schorr, J.R., et al, Source Assessment: Glass Container Manufacturing Plants, EPA Contract 68-02-1323, Task 37, October 1976, page 71.

5. Communication between Dave Powell of PES and J. Cherill, Environmental Engineer, Corning, Glass, September 28, 1977.

6. Communication between Dave Powell of PES and L. Froberg, Director of Support Science and Technology Laboratory, Owens/Corning Fiberglass, September 29, 1977.

7. Reference 1, page 23.

8. Burre, D.C., Position Paper - Proposed Regulation Change for Pressed, Blown, Spun Soda-Lime Glass Melting Furnaces, Carr-Lowrey Glass Company, October 22, 1975.

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11. Response to 114 Questionnaire by Glass Container Corporation, Fullerton, California, October 14, 1977.

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14. Arrandale, R.S., "Pollution Control in Fuel Fired Tanks," Part 5, The Glass Industry, December 1974, page 17.

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16. Response to 114 Questionnaire by Owens/Corning Fiberglas, Toledo, Ohio, November 28, 1977.

17. Reference 16.

18. Reference 16.

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24. Report Number C-2027-B, SCAQMD, Los Angeles, California, November 29, 1973.

25. Response to 114 Questionnaire from Owens-Illinois, Toledo, Ohio, October 24, 1977.

26. Preliminary data on emmission test done by the Environmental Protection Agency at Owens/Corning Fiberglas.

27. Reference 16.

28. Reference 16.

29. FMC booklet on Glass Furnace Emission Systems, FMC Corporation, Environmental Equipment Division, Itasca, Illinois, July 1977.

30. Reference 11.

31. Reference 11.

32. Report Number C-2186, SCAQMD, Los Angeles, California, January 24, 1975, January 29, 1975, January 31, 1975.

33. Reference 9.

34. Preliminary data on emission test done by the Environmental Protection Agency at Glass Containers Corporation.

35. Custer, W., "Electrostatic Cleaning of Emissions From Lead, Borosilicate, and Soda-Lime Furnaces," in Collected Papers of the 35th Annual Conference on Glass Problems, University of Ohio, 1974.

36. Reference 4, page 79.

37. Reference 25.

38. Report Number C-2205, SCAQMD, Los Angeles, California, May 2, 1975.

39. Report Number C-2232, SCAQMD, Los Angeles, California, January 7, 1975, January 28, 1975, February 27, 1975.

40. Reference 25.

41. Response to 114 Questionnaire from General Electric, Richmond Heights, Ohio, October 17, 1977.

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44. Reference 41.

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47. Reference 41.

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49. Reference 22.

50. Reference 25.

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56. Reference 35.

57. Reference 21.

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60. Communication at meeting of Owens/Corning Fiberglass representatives and Dave Powell of PES, September 29, 1977.

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62. Communication between Dave Powell of PES and B. Gallagher, Precipitaire, September 23, 1977.

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64. Reference 22.

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68. Reference 22.

5.0 MODIFICATION AND RECONSTRUCTION

5.1 GENERAL

"Modification" and reconstruction" have special meanings when applied to new source performance standards and are defined and interpreted in Title 40 of Code of Federal Regulations, Parts 60.14 and 60.15 respectively.[1] In general terms, a "modification" is any physical or operational change to an existing facility which increases emissions of certain pollutants to the atmosphere. If a change does increase emissions, then the resulting incremental emissions must be controlled to a level such that the total emissions from the facility to the atmosphere do not exceed those levels which existed before the change. In contrast to a modification, a "reconstruction" is a change which is so substantial so as to reclassify the facility as a new source rather than as an altered existing source. For this case the source may become subject to the limits of the new source performance standard.

5.2 MODIFICATION OF GLASS-PRODUCING PLANTS

Paragraph 40 CFR 60.14(a) reads as follows:

"Except as provided under paragraphs (d), (e), and (f) of this section, any physical or operational change to an existing facility which results in an increase in emission rate to the atmosphere of any pollutant to which a standard applies shall be considered a modification within the meaning of Section 111 of the Act. Upon modification, an existing facility shall become an affected facility for each pollutant to which a standard applies and for which there is an increase in the emission rate to the atmosphere."

By definition an "existing facility" is a piece of equipment or a component which was constructed prior to the date of proposal of an applicable standard of performance. An "affected facility" is a piece of equipment or a component constructed or modified after the date of proposal of an applicable standard of performance. An existing facility which undergoes a modification as defined in the Act and 40 CFR 60.14 becomes an affected facility.

As stated in the regulation, an increase in the emission rate (determined on a mass rate basis such as kg/hr) of any pollutant for which a standard applies may constitute a modification and thereby require the control of the incremental increase of emissions. Paragraph 40 CFR 60.14 (e) lists exceptions to this general rule of emission increase. The most relevant exceptions for glass manufacturing exempt the control of incremental increases in pollutants caused by the normal repair and maintenance of a glass furnace, by an increase in production if the furnace were originally capable of such an increase, and by a designed change of fuel.

To identify changes of glass melting furnace systems which should be assessed to determine if system modifications occur, the Glass Packaging Institute prepared a paper describing furnace maintenance and alterations.[2] In this paper, both cold and hot, scheduled and emergency repairs were listed. Table 5-1 shows the repairs and maintenance named in this GPI paper. Of the many furnace system changes listed, none constitute a modification of glass melting furnace systems as no emission rates of pollutants would increase.

5.3 RECONSTRUCTION OF GLASS-PRODUCING PLANTS

Paragraph 60.15 (a) and (b) read as follows:

"(a) An existing facility, upon reconstruction, becomes an affected facility, irrespective of any change in emission rate.

(b) 'Reconstruction' means the replacement of components of an existing facility to such an extent that:

Table 5-1. GPI LIST OF GLASS MELTING FURNACE MAINTENANCE AND ALTERATIONS[2]

MAINTENANCE

Cold	— Repair, patch, or rebrick	Sidewall
		Doghouse
		Throat refactory
		Melter bottom
		Ports
		Checkers
		Regenerator walls or crown
		Refiner sidewall, breastwall or bottom
	— Repair portions of superstructures	
	— Clean or replace equipment in fuel, cooling, electrical boosting, and combustion air systems	
Hot	— Operational	Fill cracks
		Replace burner blocks
		Add refractory
		Repair worn wall sections
		Repair or patch checker shafting
		Repair electrical booster electrodes
		Repair skimmer or mantle blocks
	— Non Operational	Patch hot checkers
		Repair refractory at normal glass bath level
		Reset shadow wall brick
		Repair doghouse

ALTERATIONS

Raise furnace
Deepen or expand melter
Modify regenerator
Modify combustion volume
Switch fuel

(1) The fixed capital cost of the new components exceed 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility, and

(2) It is technologically and economically feasible to meet the applicable standards set forth in this part."

The remainder of Section 60.15 specifies the information that must be submitted to the Administrator and the basis upon which a determination will be made, should an existing facility propose to replace components to the extent stated above. The term "fixed capital cost" is defined as "the capital needed to provide all the depreciable components and it is intended to include such things as costs of engineering, purchase and installation of major process equipment, contractors' fees, instrumentation, auxiliary facilities, buildings, and structures."

Of the repairs and alterations listed by the Glass Packaging Institute and shown in Table 5-1, only those involving major rebricking of a glass melting furnace may be costly enough to reclassify a furnace as a reconstructed facility. However, based on a communication from an industry representative, most repairs and alterations involving rebricking would not constitute a reconstruction. This is so despite the fact that in special cases the cost of rebricking may exceed the 50 percent of replacement cost criterion of Paragraph 40 CFR 60.15(4).[3]

5.4 REFERENCES FOR CHAPTER 5.0

1. Subpart A, Part 60, Subchapter C, Chapter 1, Title 40, Code of Federal Regulations, December 16, 1975.

2. Memorandum on Glass Container Furnace Maintenance and Alterations, John Turk, GPI, to Stanley Cuffe, EPA, dated January 12, 1978.

3. Remarks of Mr. Siegfried, representative of Johns-Manville, at NAPCTAC meeting, April 5, 1978.

6.0 ALTERNATIVE REGULATORY OPTIONS

6.1 BASIS FOR REGULATORY OPTIONS

The purpose of this chapter is to identify regulatory options for limiting particulate emissions from glass melting furnaces consistent with each category of glass manufacturing stated in Chapter 3.0. Applications of control techniques, discussed in Chapter 4.0, which meet the regulatory options are substantiated by emission tests results and by transferring appropriate technology if actual emission test results are not available.

Based on the technical discussions in Chapter 4.0, particulate emissions from glass melting furnaces can be reduced significantly by the following emission control systems:

1. All-electric melters
2. Fabric filters
3. Venturi scrubbers
4. Electrostatic precipitators

These four stand out because of their efficiency in controlling particulate emissions and because of their history of successful operation on commercial-scale units. Although all-electric melting effectively reduces particulate emissions, its use is too limited to serve as the sole basis of a regulatory standard; however, it may be utilized to meet a standard.

In the following subsections, two alternate regulatory options are listed for each glass manufacturing category and additionally for the two subcategories of pressed and blown glass formulations. In every case except for the Flat Glass category, Option I is based on the lowest level of emissions attained by the control technologies discussed in Chapter 4.0. Option II allows an emission level less stringent than Option I but, except for the Flat Glass category, it is supported by a larger data base than Option I.

The exission limits for flat glass are based on transferring the control technology used on container glass melting furnaces.

6.2 ALTERNATIVE REGULATORY OPTIONS FOR CONTAINER GLASS MANUFACTURING

6.2.1 OPTION I

Under this option, a numerical emission limit of 0.1 grams of particulate per kilogram of glass produced (0.2 pounds of particulate per ton of glass pulled) would be selected. Emission test results shown in Table 4-4 document that electrostatic precipitators would be able to comply with a standard set on this option. As shown in Table 4-2, an emission test on a furnace manufacturing products classified in the Pressed and Blown Glass category, but melted in container glass melting furnaces, suggests that an appropriately sized fabric filter would control emissions to comply with a 0.1 g/kg standard. Considering that the nature of particulate emissions from both categories is similar due to similar glass formulations and considering that the test method used for the pressed and blown furnaces biases particulate results higher than the EPA Method 5, a slightly smaller air-to-cloth ratio than that designed for this pressed and blown furnace should meet the particulate emission limit of this option. Additionally, uncontrolled all-electric melting furnaces would be able to comply with this option.

6.2.2 OPTION II

For this option, a numerical emission limit of 0.2 grams of particulate per kilogram of glass produced (0.4 pounds per ton) would be selected. All of the control techniques mentioned in Section 6.2.1, that is, electrostatic precipitators, fabric filters. and uncontrolled all-electric melters would meet this option. Additionally, based on emission test results presented in Table 4-3, venturi scrubber equipped glass container melting furnaces would comply with this option.

6.3 ALTERNATIVE REGULATORY OPTIONS FOR PRESSED AND BLOWN MANUFACTURING — SODA-LIME GLASS FORMULATIONS

6.3.1 OPTION I

Under this option, a numerical emission limit of 0.1 grams of particulate per kilogram of glass produced (corresponding to 0.2 pounds of particulate per ton) would be selected. Because the production rates of furnaces in this glass manufacturing category approximate those of container glass melting furnaces, because these pressed and blown segment furnaces are built in the same configuration as container glass melting furnaces, and because the glass formulation melted in these pressed and blown furnaces is essentially the same as that melted in container glass melting furnaces, the quantities and chemical composition of the resulting particulate approximately match those of container glass manufacturing. Therefore, the control techniques which would meet container glass Option I would be expected to comply with this option. These control techniques are: electrostatic precipitators, fabric filters with a slightly smaller air-to-cloth ratio than that listed in Table 4-2, and uncontrolled all-electric melters.

6.3.2 OPTION II

A numerical emission limit of 0.2 grams of particulate per kilogram of glass produced (equalling 0.4 pounds of particulate per ton) would be selected for this option. Paralleling the rationale of Pressed and Blown: Soda-Lime formulation OptionI, the control techniques which would be expected to comply with this option are those listed for Container Glass Option II, namely, electrostatic precipitators, fabric filters, and uncontrolled all-electric melters.

6.4 ALTERNATIVE REGULATORY OPTIONS FOR PRESSED AND BLOWN MANUFACTURING — OTHER THAN SODA-LIME FORMULATIONS

6.4.1 OPTION I

A numerical emission limit of 0.25 grams of particulate per kilogram (0.5 pounds per ton) of glass produced would be selected for the furnaces melting borosilicate, opal, lead, or other glass formulations and manufacturing products classified in the Pressed and Blown industrial category. As shown in Table 4-4, electrostatic precipitators with specific collection areas approximately three times those used for container glass melting furnaces would comply with this option for borosilicate, opal, and lead glass formulations. Additionally, fabric filters would be expected to comply based on data presented in Table 4-2.

6.4.2 OPTION II

This option consists of a numerical emission limit of 0.5 grams of particulate per kilogram (1.0 pounds per ton) of borosilicate, opal, lead, or other glass produced in melting furnaces classified in the Pressed and Blown category. Emission test results of electrostatic precipitator equipped furnace stacks show that this level of control would be achievable with a smaller specific area of collection than that required to comply with Option I. Data in Table 4-4 shows most electrostatic precipitator installations met this option. Additionally, fabric filters would be expected to comply with this option.

6.5 ALTERNATIVE REGULATORY OPTIONS FOR WOOL FIBERGLASS MANUFACTURING

The following emission limitations are written specifically for particulates emitted from glass melting furnaces and do not include particulate generated in other processing steps such as, the application of resin in the forming and finishing operations.

6.5.1 OPTION I

Under this option, a numerical limit of 0.2 grams of particulate per kilogram of glass produced (0.4 pounds per ton) would be selected. Because of test results presented in Table 4-4 that show that two of three electrostatic precipitators met the emission limit of this option, electrostatic precipitators would comply with this option as illustrated by the data shown in Table 4-2. Additionally, uncontrolled all-electric melters would comply with this option as shown in Table 4-1.

6.5.2 OPTION II

An emission limit of 0.4 grams of particulate per kilogram of glass produced (0.8 pounds per ton) would be set by this option. The use of electrostatic precipitators, fabric filters, and uncontrolled all-electric melters would comply with this emission limit.

6.6 ALTERNATIVE REGULATORY OPTIONS FOR FLAT GLASS MANUFACTURING

A numerical emission limit of 0.15 grams of particulate per kilogram of glass produced (0.3 pounds per ton) would be selected for this option. With one exception, flat glass facilities have not installed add-on control equipment to control particulate emissions; and so, in the absence of add-on control emission test results specifically for flat glass melting furnaces, this numerical emission limit is based on the similarity of particulate emissions generated from flat glass manufacture and container glass manufacture and on the percentage of particulate control attained at container glass melting furnaces.

The soda-lime formulations of flat glass and container glass are essentially identical as are the chemical composition and physical characteristics of the resulting particulate. The difference between the particulate emissions from flat glass manufacture and those from container glass manufacture is the larger quantity of solids to be collected from flat glass manufacturing. The satisfactory collection of this larger mass rate of particulate appears to present no technical difficulties (a fact which is corroborated by the guarantee underwritten by an electrostatic precipitator manufacturer for a flat glass facility). Therefore, an electrostatic precipitator would be expected to comply with this standard.

The numerical emission limit reflects the roughly 90 percent removal of particulate required in the Option I emission limits for the Container Glass, Pressed and Blown, and Wool Fiberglass industrial categories.

6.6.2 OPTION II

As mentioned at the beginning of this chapter, Option II is based on a larger emission test data base than the lowest controlled emissions on which Option I is based. Option II, therefore, allows higher particulate emissions than Option I. The upshot of comparing the numerical emission limits is that, for the previously discussed categories, the Option II emission limit is twice that of Option I. Applying this relationship to the Flat Glass category, the numerical emission limit selected for Option II would be twice that of Option I [0.3 g/kg (0.6 lb/ton)]. Again, electrostatic precipitators would be expected to comply with this option.

6.7 SUMMARY OF NUMERICAL EMISSION LIMITS

A summary of the numerical emission limits for each industrial glass manufacturing category for natural gas-fired melting furnaces is presented below:

Table 6-1. SUMMARY OF ALTERNATIVE REGULATORY OPTIONS

Glass Manufacturing Segment	Particulate Emissions					
	Uncontrolled		Option I		Option II	
	g/kg	(lb/ton)	g/kg	(lb/ton)	g/kg	(lb/ton)
Container	1.25	(2.5)	0.1	(0.2)	0.2	(0.4)
Pressed and blown: soda-lime	1.25	(2.5)	.1	(.2)	.2	(.4)
Pressed and blown: other than soda-lime	5	(10)	.25	(.5)	.5	(1.0)
Wool fiberglass	5	(10)	.2	(.4)	.4	(.8)
Flat	1.5	(3)	.15	(.3)	.3	(.6)

6.8 NUMERICAL EMISSION LIMITS FOR FUEL OIL-FIRED GLASS MELTING FURNACES

As reported in Chapter 3.0, the combustion of fuel oil for glass melting contributes particulate to the furnace exhaust. When fuel oil is burned, the allowable numerical emission limits for the regulatory options listed in this chapter will be increased 15 percent. For example, the Container Glass Option I emission limit of 0.1 g/kg (0.2 lb/ton) would be adjusted to 0.12 g/kg (0.23 lb/ton) if fuel oil were used. Similarly, the Option II value for the same category would increase from 0.2 g/kg (0.4 lb/ton) for natural gas-firing to 0.22 g/kg (0.44 lb/ton) for fuel oil-firing.

6.9 MODEL PLANT PARAMETERS

Table 6-2 lists values of operating parameters for model plants classified in each industrial category and subcategory. These model plants were generated to typify new glass melting furnaces which will be constructed in the five year period from 1978 to 1983. As such, they form one basis for determining the ambient air impact (in Chapter 7.0) and the control system cost impact (in Chapter 8.0) associated with the alternative regulatory options.

The values of the parameters were based on data encoded in the National Emission Data System (NEDS) and revised by representatives of the glass industry. Presented are values for production rate, stack height, stack diameter, stack gas exit velocity, stack gas temperature, particulate emissions and emission rates. Exhaust gas velocities are calculated for the model plants assuming a 10.5 percent oxygen concentration in the furnace exhaust, which corresponds to 100 percent excess oxygen. Stack diameters are then calculated to maintain a 30 fps stack gas exit velocity. Additionally, the exhaust flow rates shown for fabric filter applications are larger than the uncontrolled furnace rates because of the addition of cooling air.

6.10 COMPARISON OF ALTERNATIVE REGULATORY OPTIONS WITH STATE COMPLIANCE LIMITS FOR EXISTING GLASS FACILITIES

To gauge the magnitude of emission rates proposed by the alternative regulatory options in contrast to the compliance limits allowed by the states in which glass facilities are located, emission rates for model plants in each industry category as set in both options are tabled with emission rates corresponding to the compliance limits for existing glass facilities located in New Jersey. The current New Jersey regulations are shown because they represent a rough average of the states' compliance limits discussed in Chapter 3.0.

As seen in Table 6-3 for all cases, both options represent more stringent emission rates than the New Jersey compliance regulations. In particular for the Container category, representing the largest production capacity of all glass industry segments, Option I represents 19 percent of the state emission value and Option II represents 39 percent.

Table 6-2. MODEL PLANT PARAMETERS

		Container Glass				Wool Fiberglass			
		Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace	Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace
Production rate	Mg/day (tpd)	227 (250)	227 (250	227 (250)	227 (250)	181.6 (200)	181.6 (200)	- -	181.6 (200)
Stack height	m (ft)	21.3 (70)	25.9 (85)	18.3 (60)	18.3 (60)	27.4 (90)	25.9 (85)	- -	18.3 (60)
Stack diameter	m (ft)	2.29 (7.5)	2.07 (6.8)	1.74 (5.7)	2.29 (7.5)	1.89 (6.2)	1.71 (5.6)	- -	1.89 (6.2)
Stack exit velocity	mps (fps)	9.14 (30)	9.14 (30)	9.14 (30)	9.14 (30)	9.14 (30)	9.14 (30)	- -	9.14 (30)
Stack flow rate	m^3/s (acfm)	37.76 (80,000)	30.68 (65,000)	21.80 (46,200)	37.61 (79,700)	25.86 (54,800)	21.05 (44,600)	- -	25.86 (54,800)
Stack temperature	°K (°F)	590 (603)	480 (405)	340 (153)	590 (603)	590 (603)	480 (405)	- -	590 (603)
Particulate emissions									
Uncontrolled	g/kg (lb/ton)	1.25 (2.5)	- -	- -	- -	5 (10)	- -	- -	- -
Option I	g/kg (lb/ton)	- -	.1 (.2)	- -	.1 (.2)	- -	0.2 (0.4)	- -	0.2 (0.4)
Option II	g/kg (lb/ton)	- -	.2 (.4)	.2 (.4)	.2 (.4)	- -	0.4 (0.8)	- -	0.4 (0.8)
Particulate emission rate									
Uncontrolled	g/s (lb/hr)	3.3 (26)	- -	- -	- -	10.5 (83.3)	- -	- -	- -
Option I	g/s (lb/hr)	- -	.26 (2.1)	.26 (2.1)	.26 (2.1)	- -	.42 (3.3)	- -	.42 (3.3)
Option II	g/s (lb/hr)	- -	.53 (4.2)	.53 (4.2)	.53 (4.2)	- -	.84 (6.6)	- -	.84 (6.6)

Table 6-2. MODEL PLANT PARAMETERS (Continued)

		Pressed and Blown: Soda Lime — 50 TPD Case				Pressed and Blown: Soda Lime — 100 TPD Case			
		Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace	Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace
Production rate	Mg/day (tpd)	45.4 (50)	45.4 (50)	- -	45.4 (50)	90.8 (100)	90.8 (100)	- -	90.8 (100)
Stack height	m (ft)	27.4 (90)	25.9 (85)	- -	18.3 (60)	27.4 (90)	25.9 (85)	- -	18.3 (60)
Stack diameter	m (ft)	1.02 (3.36)	1.02 (3.36)	- -	1.14 (3.73)	1.45 (4.76)	1.45 (4.76)	- -	1.61 (5.27)
Stack exit velocity	mps (fps)	9.14 (30)	9.14 (30)	- -	9.14 (30)	9.14 (30)	9.14 (30)	- -	9.14 (30)
Stack flow rate	m^3/s (acfm)	7.55 (16,000)	7.55 (16,000)	- -	9.30 (19,700)	15.10 (32,000)	15.10 (32,000)	- -	18.55 (39,300)
Stack temperature	°K (°F)	480 (405)	480 (405)	- -	590 (603)	480 (405)	480 (405)	- -	590 (603)
Particulate emissions									
Uncontrolled	g/kg (lb/ton)	1.25 (2.5)	- -	- -	- -	1.25 (2.5)	- -	- -	- -
Option I	g/kg (lb/ton)	- -	.1 (.2)	- -	.1 (.2)	- -	.1 (.2)	- -	.1 (.2)
Option II	g/kg (lb/ton)	- -	.2 (.4)	- -	.2 (.4)	- -	.2 (.4)	- -	.2 (.4)
Particulate emission rate									
Uncontrolled	g/s (lb/hr)	.66 (5.21)	- -	- -	- -	1.3 (10.4)	- -	- -	- -
Option I	g/s (lb/hr)	- -	.06 (.04)	- -	.06 (0.4)	- -	.11 (.8)	- -	.11 (.8)
Option II	g/s (lb/hr)	- -	.11 (.8)	- -	.11 (.8)	- -	.21 (1.6)	- -	.21 (1.6)

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Table 6-2. MODEL PLANT PARAMETERS (Continued)

		Pressed and Blown: Other Than Soda Lime — 50 TPD Case				Pressed and Blown Other Than Soda Lime — 100 TPD Case			
		Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace	Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace
Production rate	Mg/day (tpd)	45.4 (50)	45.4 (50)	- -	45.4 (50)	90.8 (100)	90.8 (100)	- -	90.8 (100)
Stack height	m (ft)	27.4 (90)	25.9 (85)	- -	18.3 (60)	27.4 (90)	25.9 (85)	- -	18.3 (60)
Stack diameter	m (ft)	1.02 (3.36)	1.02 (3.36)	- -	1.14 (3.37)	1.45 (4.75)	1.45 (4.75)	- -	1.61 (5.27)
Stack exit velocity	mps (fps)	9.14 (30)	9.14 (30)	- -	9.14 (30)	9.14 (30)	9.14 (30)	- -	9.14 (30)
Stack flow rate	m^3/s (acfm)	7.55 (16,000)	7.55 (16,000)	- -	9.30 (19,700)	15.10 (32,000)	15.10 (32,000)	- -	18.55 (39,300)
Stack temperature	°K (°F)	480 (405)	480 (405)	- -	590 (603)	480 (405)	480 (405)	- -	590 (603)
Particulate emissions									
Uncontrolled	g/kg (lb/ton)	5 (10)	- -	- -	- -	5 (10)	- -	- -	- -
Option I	g/kg (lb/ton)	- -	.25 (.5)	- -	.25 (.5)	- -	.25 (.5)	- -	.25 (.5)
Option II	g/kg (lb/ton)	- -	.5 (1.0)	- -	.5 (1.0)	- -	.5 (1.0)	- -	.5 (1.0)
Particulate emission rate									
Uncontrolled	g/s (lb/hr)	2.6 (20.8)	- -	- -	- -	5.3 (41.7)	- -	- -	- -
Option I	g/s (lb/hr)	- -	.13 (1.0)	- -	.13 (1.0)	- -	.26 (2.1)	- -	.26 (2.1)
Option II	g/s (lb/hr)	- -	.26 (2.1)	- -	.26 (2.1)	- -	.53 (4.2)	- -	.53 (4.2)

Table 6-2. MODEL PLANT PARAMETERS (Concluded)

		Flat			
		Uncontrolled Furnace	Fabric Filter Controlled Furnace	Scrubber Controlled Furnace	Electrostatic Precipitator-Controlled Furnace
Production rate	Mg/day (tpd)	635.6 (700)	- -	- -	635.6 (700)
Stack height	m (ft)	21.3 (70)	- -	- -	18.3 (60)
Stack diameter	m (ft)	4.39 (14.4)	- -	- -	4.39 (14.4)
Stack exit velocity	mps (fps)	9.14 (30)	- -	- -	9.14 (30)
Stack flow rate	m^3/s (acfm)	138.28 (293,000)	- -	- -	138.28 (293,000)
Stack temperature	°K (°F)	480 (405)	- -	- -	480 (405)
Particulate emissions					
Uncontrolled	g/kg (lb/ton)	1.5 (3.0)	- -	- -	- -
Option I	g/kg (lb/ton)	- -	- -	- -	.15 (.3)
Option II	g/kg (lb/ton)	- -	- -	- -	.3 (.6)
Particulate emission rate					
Uncontrolled	g/s (lb/hr)	11.0 (87.5)	- -	- -	- -
Option I	g/s (lb/hr)	- -	- -	- -	1.10 (8.75)
Option II	g/s (lb/hr)	- -	- -	- -	2.21 (17.5)

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Table 6-3. COMPARISON OF ALTERNATIVE REGULATORY OPTIONS WITH NEW JERSEY STATE COMPLIANCE REGULATIONS

Industry Category	Pull Rate TPD	Alternative Regulatory Options				Current New Jersey Regulations	
		Option I		Option II			
		g/s	(lb/hr)	g/s	(lb/hr)	g/s	(lb/hr)
Flat	700	1.1	(8.75)	2.21	(17.5)	2.7	(21.4)
Container	250	.26	(2.1)	.53	(4.2)	1.4	(10.9)
Pressed and Blown: Soda-lime	50	.06	(.4)	.11	(.8)	.78	(6.2)
Pressed and Blown: Soda-lime	100	.11	(.8)	.21	(1.6)	.93	(7.4)
Pressed and Blown: Other than Soda-lime	50	.13	(1.0)	.26	(2.1)	.78	(6.2)
Pressed and Blown: Other than Soda-lime	100	.26	(2.1)	.53	(4.2)	.93	(7.4)
Wool Fiberglass	200	.42	(3.3)	.84	(6.6)	1.2	(9.7)

7.0 ENVIRONMENTAL IMPACT

7.1 AIR QUALITY IMPACT

7.1.1 PRIMARY AIR QUALITY IMPACT

7.1.1.1 Introduction

This section assesses the air quality impact of the regulatory options enumerated in Chapter 6.0 for new glass producing facilities built in the period from 1978 to 1983. Ambient air particulate concentrations and contributions to the national particulate emission inventory provide the means to quantify the air quality impact. A computer dispersion model predicts the ambient air particulate concentration from model plants of each industrial category (Table 6-2) for the following cases: an emission rate from an uncontrolled furnace; an emission rate which matches the State Implementation Plan (SIP) regulations, as typified by current New Jersey regulations; and emission rates matching the numerical limits of the regulatory options. The other element of measuring air quality impact, the contribution to the national particulate emission inventory, is determined by proportioning the uncontrolled furnace emissions to the degree emission reduction realized by the SIP regulations and by the regulatory options. The air quality assessment consists of comparing the ambient air particulate concentrations and the particulate emission inventory impacts resulting from model plants meeting the regulatory options with those from uncontrolled furnaces, with those from facilities whose emissions satisfy the SIP regulations, and finally comparing the impact of each regulatory option.

Table 7-1 shows, for each glass category, projected amounts of glass produced from new facilities at the end of the 5 year period from 1978 to 1983 and the amounts of particulate emissions released by these facilities, if uncontrolled. These figures are derived

Table 7-1. GLASS INDUSTRY GROWTH IN THE PERIOD FROM 1978 TO 1983

Industry Category	Annual Growth Rate	New Growth		Uncontrolled Particulate Emissions	
	Percent	g x 10^{12}	Tons x 10^6	g x 10^9	Tons x 10^3
Container	3.1	1.94	(2.13)	2.4	(2.7)
Pressed and blown: soda-lime	3.5	0.25	(0.28)	0.31	(0.34)
Pressed and blown: other than soda-lime	3.5	0.07	(0.08)	0.35	(0.39)
Wool fiberglass	7.1	0.36	(0.40)	1.8	(2.0)
Flat	1.8	0.24	(0.26)	0.36	(0.40)

from the production rates, the annual growth rates, and the uncontrolled emission rates listed in Chapter 3.0.

The Industrial Source Complex Dispersion Model Short-Term Computer Program (ISCST) was used to calculate the magnitudes and locations of maximum ground-level particulate concentrations for each of the regulatory options.[1] The ISCST program corresponds to the EPA single source model (CRSTER) modified to include the effects of aerodynamic downwash on plume dispersion. No effects of fugitive emissions were taken into account in this study. Additional program inputs were meteorological information from the Greater Pittsburgh Airport and the stack parameters listed in Table 6-2.

In order to simplify analysis, the current New Jersey regulations were chosen to typify the norm of SIP particulate emission regulations. In all glass categories except the Pressed and Blown: soda-lime category (50 ton per day furnace), the SIP allowable emissions for model plants are less than the uncontrolled furnace emissions. For the Pressed and Blown: soda-lime category, the SIP allowable emissions for the 50 ton per day furnace are essentially identical to the uncontrolled furnace particulate emissions.

7.1.1.2 Container Glass Category

As displayed in Table 7-2, the maximum ground-level particulate concentration from the model plant varies with the control equipment installed for each regulatory option. Implementation of regulatory Option I would reduce the 24-hour maximum particulate concentration emitted by an uncontrolled furnace by 93 percent with a fabric filter and by 91 percent with an electrostatic precipitator. Option I also reduces 24-hour maximum particulate concentrations allowed by the SIP regulation by 82 percent with a fabric filter and by 78 percent with an electrostatic precipitator. For all these estimations, the maximum particulate concentration occurs 300 meters from the stack at the plant boundary. Based on an annual arithmetic average, the 0.6 $\mu g/m^3$ particulate concentration resulting from the uncontrolled furnace is reduced to 0.1 $\mu g/m^3$, both by a fabric filter sized for Option I and by an appropriately designed electrostatic precipitator. All three particulate maxima occur 300 meters from the stack.

Control equipment which can be selected for Option II are fabric filters, venturi scrubbers, and electrostatic precipitators. On a 24-hour basis, the fabric filter reduces the maximum particulate concentration emitted by an uncontrolled furnace by 85 percent; the venturi scrubber reduces the concentration by 45 percent; and, the electrostatic precipitator reduces the concentration by 82 percent. The fabric filter and electrostatic precipitator sized

Table 7-2. CONTAINER GLASS CATEGORY

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled furnace	10.8	0.3	0.6	0.3
SIP regulation	4.5	0.3	0.3	0.3
Fabric filter meeting Option I - 92% control	0.8	0.3	0.1	0.3
Fabric filter meeting Option II - 84% control	1.6	0.3	0.1	0.3
Venturi scrubber meeting Option II - 84% control	5.9	0.3	0.6	0.3
Electrostatic precipitator meeting Option I - 92% control	1.0	0.3	0.1	0.3
Electrostatic precipitator meeting Option II - 84% control	1.9	0.3	0.1	0.3

* Arithmetic mean

for Option II reduce the maximum particulate concentration allowed by SIP regulation by 64 percent and 58 percent, respectively. The particulate concentration 300 meters from a venturi scrubber stack is predicted to be greater than the particulate concentration from a model container glass furnace meeting the SIP particulate emission regulation. On an annual basis, the maximum particulate concentrations from stacks equipped with a fabric filter or electrostatic precipitator sized for Option II are 0.1 $\mu g/m^3$, representing an 83 percent reduction from the uncontrolled furnace. Controlling emissions by venturi scrubber does not reduce maximum particulate concentrations from the uncontrolled case for the annual average calculation.

Implementing the SIP particulate emission regulation would reduce the uncontrolled furnace maximum particulate concentrations by 58 percent on a 24-hour basis and by 50 percent on an annual average basis.

Although dependent on selection of control equipment, Option I, in general, represents a 50 percent reduction in 24-hour maximum particulate concentration over Option II. On the annual average basis, there is no estimated reduction in the maximum particulate concentration from Option I as compared to Option II.

As shown in Table 7-1, the projected additional contribution to the national particulate emission inventory from uncontrolled container glass facilities brought on-stream in the period from 1978 to 1983 is projected to be 2.4×10^9 grams (2,700 tons). Meeting SIP emissions reduces this amount to 1.0×10^9 grams (1,100 tons). Implementing Option II reduces the uncontrolled furnace emissions by 84 percent -- a reduction of 2.0×10^9 grams (2,300 tons). Option II represents a 62 percent reduction in the SIP particulate emissions and captures 6.2×10^8 grams (680 tons) more particulate than container glass furnaces controlled to the SIP levels. Option I control reduces uncontrolled furnace particulate emissions 2.2×10^9 grams (2,500 tons), an amount equaling a 92 percent reduction of the uncontrolled emissions. As compared to the SIP allowable emissions, Option I captures 8.1×10^8 grams

(890 tons) more particulate, which represents an 81 percent reduction of of the SIP allowable emissions. Option I control reduces Option II particulate emissions by 50 percent or 1.9 x 10^8 grams (210 tons).

7.1.1.3 Pressed and Blown: Soda-Lime Category

In this section ambient air analyses are made for two characteristic sizes of furnaces -- a 50 TPD small furnace and a 100 TPD larger furnace, as shown in Tables 7-3 and 7-4 respectively. However, the contribution to the national particulate emission inventory is based on the entire category. As mentioned previously, the particulate emissions allowed by SIP regulations are assumed to be identical to the uncontrolled furnace emissions from a 50 TPD furnace. For this case, the impacts of the controlled to the SIP regulations and the uncontrolled emissions are also identical.

For the 50 TPD furnace size (Table 7-3) Option I and II ambient particulate concentrations depend on the control technique used. On a 24-hour basis, the maximum ground-level particulate concentration for uncontrolled furnaces and emissions controlled to SIP regulations is 2.7 $\mu g/m^3$. Implementing Option I would reduce the maximum particulate concentration by 93 percent with a fabric filter and by 89 percent with an electrostatic precipitator with all maxima occurring 300 meters from the stack. Both types of control equipment reduce the annual average maximum particulate concentration below 0.1 $\mu g/m^3$, although in this case, maxima occur 500 meters from the stack.

Selecting equipment to satisfy Option II for the 50 TPD furnace size would reduce the 24-hour maximum particulate concentration from uncontrolled furnaces and furnaces controlled to the SIP regulation by 81 percent with a fabric filter and by 78 percent with an electrostatic precipitator. The annual average maximum particulate concentrations from both devices is less than 0.1 $\mu g/m^3$ at 500 meters from the stack.

Table 7-3. PRESSED AND BLOWN: SODA-LIME 50 TPD
MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled and SIP regulation	2.7	0.3	0.2	0.5
Fabric filter meeting Option I - 92% control	0.2	0.3	<0.1	0.5
Fabric filter meeting Option II - 84% control	0.5	0.3	<0.1	0.5
Electrostatic precipitator meeting Option I - 92% control	0.3	0.3	<0.1	0.5
Electrostatic precipitator meeting Option II - 84% control	0.6	0.3	<0.1	0.5

* Arithmetic mean

On a 24-hour basis, Option I represents, in general, a 55 percent reduction in emissions as compared to Option II emissions. On the annual average basis, Option I and Option II present identical impacts.

For the 100 TPD furnace size (Table 7-4), Option I reduces the 24-hour maximum particulate concentration from the uncontrolled furnace case by 94 percent using a fabric filter and by 88 percent using an electrostatic precipitator. Option I reduces the maximum concentration as compared to the SIP case by 92 percent using a fabric filter and by 83 percent using an electrostatic precipitator.

Table 7-4. PRESSED AND BLOWN: SODA-LIME TO 100 TPD

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled	3.4	0.3	0.2	0.3
SIP Regulation	2.4	0.3	0.1	0.3
Fabric filter meeting Option I - 92% control	0.2	0.3	<0.1	0.3
Fabric filter meeting Option II - 84% control	0.6	0.3	<0.1	0.3
Electrostatic precipitator meeting Option I - 92% control	0.4	0.3	<0.1	0.3
Electrostatic precipitator meeting Option II - 84% control	0.7	0.3	<0.1	0.3

*Arithmetic mean

Installing either control system sized for Option I reduces the annual averaged particulate concentration from 0.2 $\mu g/m^3$ for an uncontrolled model furnace and from 0.1 $\mu g/m^3$ for a furnace controlled to the SIP regulations to less than 0.1 $\mu g/m^3$.

Implementing Option II with a fabric filter realizes an 82 and a 75 percent reduction in the uncontrolled furnace and the SIP regulation 24-hour maximum particulate concentrations, respectively, as compared to a 79 and 71 percent reduction realized with an electrostatic precipitator. Annual maxima averages show identical results as the Option I estimation for this furnace size.

On the average, Option I emission control results in a 54 percent reduction in the 24-hour particulate concentration as compared to Option II emission control, but on an annual basis, Option I and Option II yield identical maximum particulate concentrations.

Uncontrolled new furnaces in this category, commissioned in the 1978 to 1983 period of interest, are projected to release an additional 3.1×10^8 grams (340 tons) of particulate to the atmosphere. The following quantities are based on the assumption that 26 percent of the pressed and blown glass is made in 50 TPD furnaces.

Particulate control to the SIP regulation by the 100 TPD furnaces reduces the uncontrolled particulate emissions to 1.6×10^8 grams (180 tons). Option II reduces the uncontrolled amount by 1.9×10^8 grams (210 tons); Option I reduces the the uncontrolled amount by 2.1×10^8 grams (230 tons). Option I controls 4.5×10^7 (50 tons) more than the state regulation and Option II controls 2.7×10^7 grams (30 tons) more than the state regulation. Option I, therefore, captures 1.8×10^7 grams (20 tons) more particulate emissions than Option II.

For the 50 TPD furnaces in this category: Option I reduces the uncontrolled particulate emissions by 7.7×10^7 grams (85 tons); Option II reduces the uncontrolled amount by 6.8×10^7 grams (75 tons). Thus, Option I controls 9×10^6 grams (10 tons) more particulate than Option II. As previously noted, the SIP regulation and the uncontrolled furnace emissions are identical.

The contribution to the national particulate emission inventory is based on the entire category. Thus, overall, Option I reduces the uncontrolled particulate emissions by 2.9×10^8 grams (315 tons); Option II reduces the uncontrolled amount by 2.6×10^8 grams (285 tons). Option I controls 2.7×10^7 grams (30 tons) more particulate than Option II.

7.1.1.4 Pressed and Blown: Other Than Soda-Lime Category

The analysis for this industrial category parallels the Pressed and Blown: soda-lime analysis in that the impacts for two furnace sizes are estimated (a 50 TPD and a 100 TPD pull rate). However, the analysis of the "other soda-lime" subcategory differs from the "soda-lime" subcategory in that the emissions allowed under the SIP provisions for the 50 TPD furnace are not identical to the uncontrolled furnace particulate emissions. The ambient particulate concentration estimations are illustrated in Table 7-5 for a 50 TPD furnace and in Table 7-6 for a 100 TPD furnace. The particulate emissions allowed by the SIP vary with process (or production) rate, and so, to determine the SIP impact on national particulate emission inventory, the proportion of each furnace size must be determined. The impact is estimated assuming 26 weight percent of the additional glass produced in this subcategory from 1978 to 1983 is processed in the smaller sized furnace. This assumption is based on National Emission Data System information for the entire Pressed and Blown (N.E.C.) classification.[2]

For a 50 TPD furnace (Table 7-5), the uncontrolled emissions result in a 24-hour maximum particulate concentration of 10.7 $\mu g/m^3$ The allowable particulate emissions under the SIP regulations reduce the uncontrolled furnace particulate emissions by 70 percent. Controlling particulate emissions to Option I levels reduces the 24-hour maximum value for an uncontrolled furnace by 93 percent and the SIP emissions by 78 percent. The uncontrolled furnace

Table 7-5. PRESSED AND BLOWN: OTHER THAN SODA-LIME 50 TPD

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled furnace	10.7	0.3	0.8	0.5
SIP regulation	3.2	0.3	0.2	0.5
Fabric filter meeting Option I - 95% control	0.7	0.3	<0.1	0.5
Fabric filter meeting Option II - 90% control	1.3	0.3	0.1	0.5
Electrostatic precipitator meeting Option I - 95% control	0.7	0.3	<0.1	0.3
Electrostatic precipitator meeting Option II - 90% control	1.0	0.3	0.1	0.3

* Arithmetic mean

annual average maximum particulate concentration of 0.8 $\mu g/m^3$ is reduced to less than 0.1 $\mu g/m^3$ by Option I control.

Option II reduces the 24-hour maximum particulate concentration of an uncontrolled furnace by 88 percent with a fabric filter and by 91 percent with an electrostatic precipitator. On a 24-hour basis Option II - a fabric filter reduces the SIP concentrations by 59 percent and an Option II - electrostatic precipitator, by 69 percent. On an annual average basis Option II control devices realize an 88 percent reduction in particulate concentrations from uncontrolled furnace emissions and a 50 percent reduction in the

Table 7-6. PRESSED AND BLOWN: OTHER THAN SODA-LIME TO 100 TPD

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR
AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled furnace	13.9	0.3	0.9	0.3
SIP regulation	2.5	0.3	0.2	0.3
Fabric filter meeting Option I - 95% control	0.8	0.3	<0.1	0.3
Fabric filter meeting Option II - 90% control	1.5	0.3	0.1	0.3
Electrostatic precipitator meeting Option I - 95% control	0.9	0.3	<0.1	0.3
Electrostatic precipitator meeting Option II - 90% control	1.9	0.3	0.1	0.3

* Arithmetic mean

particulate concentrations from furnaces controlled to the SIP regulations.

For the 100 TPD furnace (Table 7-6), the relevant comparisons for 24-hour particulate concentrations are: Option I - fabric filter, a 94 percent reduction in the uncontrolled case, a 68 percent reduction from the SIP provisions; Option I - electrostatic precipitator, a 94 percent reduction in the uncontrolled case, a 64 percent reduction from the SIP provisions. Comparisons for Option

II are: Option II - fabric filter, an 89 percent reduction in the uncontrolled case, a 40 percent reduction from the SIP provisions; Option II - electrostatic precipitator, an 86 percent reduction in the uncontrolled case, a 24 percent reduction from the SIP provisions. On an annual basis, Option I control devices reduce concentrations to less than 0.1 $\mu g/m^3$; Option II devices reduce concentrations to 0.1 $\mu g/m^3$, representing an 89 percent reduction for uncontrolled furnaces and a 50 percent reduction for the SIP regulations. All maxima occur 300 meters from the stack.

Implementing Option I reduces Option II 24-hour maximum particulate concentrations about 50 percent.

As listed in Table 7-1, particulate emissions from new furnaces in this subcategory, if uncontrolled, are projected to contribute an additional 3.5×10^8 grams (390 tons) of particulate to the national particulate emission inventory. The SIP provisions decrease this amount to 7.4×10^7 grams (80 tons), assuming 26 weight percent of the glass will be manufactured in 50 TPD furnaces. Implementing Option II controls capture 3.2×10^8 grams (350 tons) more particulate than the uncontrolled furnace emissions, for a 90 percent reduction. As compared to the SIP provisions, Option II controls 3.6×10^7 grams (40 tons) more particulate for a 50 percent reduction. Implementing Option I reduces particulate emissions by 3.3×10^8 grams (370 tons) more than the uncontrolled furnace case, 5.4×10^7 grams (60 tons) more than the SIP provisions, and 1.8×10^7 grams (20 tons) more than the Option II controls. Percent reductions for these comparisons are: 95 percent; 75 percent; and 50 percent, respectively.

7.1.1.5 Wool Fiberglass Category

As seen in Table 7-7, the impact of Option I controls on the 24-hour maximum particulate concentration depends on the control system selected. A fabric filter designed for this option reduces the uncontrolled furnace maximum particulate concentration by 94 percent and the SIP allowable emissions by 48 percent. An electrostatic precipitator sized for Option I reduces the uncontrolled furnace value by 93 percent and the SIP provision value by 39 percent. On an annual basis, Option I controls reduce uncontrolled furnace concentrations by 94 percent and the SIP concentrations by 50 percent.

Table 7-7. WOOL FIBERGLASS

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled furnace	28.7	0.3	1.8	0.3
SIP regulation	3.3	0.3	0.2	0.3
Fabric filter meeting Option I - 98% control	1.7	0.3	0.1	0.3
Fabric filter meeting Option II - 96% control	3.4	0.3	0.2	0.3
Electrostatic precipitator meeting Option I - 98% control	2.0	0.3	0.1	0.3
Electrostatic precipitator meeting Option II - 96% control	4.0	0.3	0.3	0.3

* Arithmetic mean

Systems meeting Option II emission limits also vary in air quality impact. A fabric filter reduces 24-hour maximum particulate concentration from an uncontrolled furnace by 88 percent, whereas, an electrostatic precipitator reduces the uncontolled furnace value by 86 percent. For both control devices, the 24-hour maximum particulate concentrations are higher than the value for the SIP allowable emissions. On an annual basis, Option II control devices reduce maximum particulate concentrations from uncontrolled furnaces by 89 percent with a fabric filter, and by 83 percent with an electrostatic precipitator. Maximum particulate concentrations resulting from these devices match or exceed those resulting from the SIP regulations.

Uncontrolled furnaces in this category are projected to contribute an additional 1.8×10^9 grams (2,000 tons) to the national particulate emission inventory. The SIP regulations lower these emissions to 2.1×10^8 grams (230 tons). Implementing Option II controls captures 1.7×10^9 grams (1,920 tons) more particulate than the uncontrolled furnace emission -- a 96 percent reduction. Option II represents a 65 percent reduction in the SIP emissions or captures 1.4×10^8 grams (150 tons more particulate). Option I controls realize a 98 percent reduction in uncontrolled furnace emissions (1.76×10^9 grams or 1,960 tons of particulate captured), an 83 percent reduction in the SIP particulate emissions (1.7×10^8 grams or 190 tons of particulate captured), and a 50 percent reduction in Option II emissions (3.6×10^7 grams or 40 tons of particulate captured).

7.1.1.6 Flat Glass Category

Only the air quality impact of electrostatic precipitator systems are computed for the Flat Glass category. Option I reduces the uncontrolled furnace 24-hour maximum particulate concentration by 89 percent, the SIP provision 24-hour value by 54 percent, and the Option II 24-hour values by 49 percent. The uncontrolled furnace annual average maximum particulate concentration of 0.6 $\mu g/m^3$ is reduced by Option I control to less than 0.1 $\mu g/m^3$

Option II reduces the uncontrolled furnace 24-hour maximum particulate concentration by 78 percent and the SIP provision by 10 percent. This option, on an annual basis, reduces the uncontrolled furnace maximum particulate concentration by 75 percent. The annual average value for Option II equals the SIP regulation maximum particulate concentration.

Uncontrolled furnace emissions from new furnaces are projected to contribute an additional 3.6×10^8 grams (400 tons) of particulate to the national emission inventory. Meeting the SIP provisions drops this amount to 8.8×10^7 grams (97 tons). Implementing Option II reduces uncontrolled furnace emissions by 2.9×10^8 grams (320 tons), equaling an 80 percent reduction. Option II also reduces the SIP provision emissions by 1.6×10^7 grams (18 tons), for an 18 percent reduction. Option I reduces uncontrolled furnace emissions by 3.2×10^8 grams (360 tons), for an 90 percent reduction, reduces the SIP emissions by 5.2×10^7 grams (57 tons), and a 59 percent reduction in the SIP allowed emissions, and reduces Option II emissions by 3.6×10^7 grams (40 tons), or a 50 percent reduction in Option II emissions.

7.1.1.7 Summary of Air Quality Impact

As shown in Tables 7-2 to 7-8, for all glass categories, implementing Option I would reduce the 24-hour maximum particulate concentration from uncontrolled furnaces by about 90 percent. Control to Option II levels reduces this uncontrolled furnace maximum

Table 7-8. FLAT GLASS

MAGNITUDES OF AND DISTANCES TO MAXIMUM 24-HOUR AND ANNUAL AVERAGE PARTICULATE CONCENTRATIONS

Case	24 Hour		Annual*	
	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance (km)
Uncontrolled furnace	20.5	0.3	0.6	0.3
SIP regulations	5.0	0.3	0.15	0.3
Electrostatic precipitator meeting Option I - 90% control	2.3	0.3	<0.1	0.3
Electrostatic precipitator meeting Option II - 80% control	4.5	0.3	0.15	0.3

* Arithmetic mean

by about 85 percent. Option I, in general, reduces the SIP allowed 24-hour maximum particulate concentrations by about 80 percent, except for the Wool Fiberglass and Flat Glass categories, where the reduction averaged about 50 percent. Option II controls reduce concentrations predicted under the SIP regulations by about 60 percent in the Container, Pressed and Blown: soda-lime, and Pressed and Blown: other than soda-lime categories. Impacts from implementing Option II controls in the other two categories do not differ from the SIP provision impacts. In general, Option I represents a 50 percent reduction in the Option II 24-hour maximum particulate concentration.

Total particulate emissions from uncontrolled furnaces placed onstream from 1978 to 1983 in all glass categories is projected to be 5.2×10^9 grams (5,740 tons). Meeting the state regulations (SIP) lowers this total to 1.5×10^9 grams (1,670 tons). Option I reduces uncontrolled emissions by 4.8×10^9 grams (5,370 tons); and, Option II by 4.6×10^9 grams (5,000 tons). As compared to the state regulations, Option I reduces additional particulate emissions by 1.1×10^9 grams (1,200 tons); and, Option II by 0.9×10^9 grams (990 tons). Option I reduces Option II emissions by 3.4×10^8 grams (370 tons).

The ambient particulate concentrations resulting from model plants (Tables 7-2 to 7-8) are much less than the national primary and secondary air standards for total suspended particulates. However, with the exception of the Pressed and Blown: soda-lime category, the maximum partculate concentrations on a 24-hour basis from all uncontrolled furnaces exceed the Prevention of Significant Deterioration - Class I increment of 10 $\mu g/m^3$. The maximum particulate concentrations resulting from these uncontrolled furnaces do not exceed the Class II increment of 37 $\mu g/m^3$.

7.1.2 SECONDARY AIR QUALITY IMPACT

As all of the energy supplied to the control systems is in the form of electricity, use of these systems transfers the source of particulate emissions from the glass manufacturing facility to the electric utility plant. The amounts of this secondary air impact can be estimated from the electrical requirements of implementing the regulatory options and the SIP regulations as presented in Section 7.4. The bases for these estimates are the range of energy impacts listed in Section 7.4 and a utility boiler emission factor of 0.1 pounds of particulate for one million Btu's of heat input as reported in the New Source Performance Standard for Fossil Fuel-Fired Boilers.[3] Embedded in the energy impacts is a utility boiler thermal efficiency expressed as 10,000 Btu/kWh representing an efficiency of 34 percent. Results of these calculations are:

Option I	9,300 kg (10.2 tons) to 25,800 kg (28.4 tons)
Option II	9,300 kg (10.2 tons) to 32,300 kg (35.6 tons)
SIP provisions	8,300 kg (9.1 tons) to 29,500 kg (32.4 tons)

In all cases, the particulate emissions from the utility plant are two orders of magnitude less than the uncontrolled glass particulate emissions.

7.2 WATER POLLUTION IMPACT

The glass manufacturing process has minimal water pollution potential. Any water, added to batch materials to prevent dusting, generated by chemical reaction, or sprayed into the furnace exhaust for cooling, is vaporized and is swept out of the stack as vapor.

Option I presents no water pollution potential as control systems meeting this option do not discharge water streams.

The only control system meeting Option II which presents any potential water pollution potential impact is the venturi scrubber. Although each venturi system discharges approximately 1.3×10^{-4} m^3/s (2 gpm) of waste containing about 95 percent water, the total water pollution impact is negligible as few glass container facilities are anticipated to utilize this control system.[4]

In summary, control of particulate emissions is expected to pose a negligible source of water pollution. State regulations will not be different than these impacts.

7.3 SOLID WASTE IMPACT

Add-on control systems generate solids as a byproduct of lowering glass melting furnace particulate emissions. At present, these solids are not an economically attractive source of chemicals, and they are not expected to be a usable source in the future. In general, the solids can be disposed of through recycling back into the glass melting process or through landfilling. Recycling is technically feasible for many types of glass since the chemicals in the waste are also present in the raw batch materials. Landfilling has been popular in the glass industry since no additional equipment is required to dispose of the solids for most glasses. Plant visits showed that landfilling was uniformly used as the method of solid disposal.

There are certain limitations or disadvantages to these methods of disposal. Recycling may be limited in extent because of the composition of the solid waste not being compatible with the batch recipe of a specific product. Preparing the solids for landfilling may be required for solid wastes containing potentially hazardous dusts. Also, if available landfill area were restricted, an alternate method of disposal would be necessitated.

The amounts of solid waste generated in the control of particulates from glass manufacturing is identical to the amount of particulate removed from stack gases. Therefore, Option I will generate 4.8×10^9 grams (5,370 tons), Option II will generate 4.6×10^9 grams (5,000 tons); and meeting the state regulations will generate 1.5×10^9 grams (1,670 tons). Comparing Option I and Option II for solid waste impact shows them to be essentially equal; Option I requires disposal of 7 percent more collected particulate. Option I and Option II require about three times more solids collected to be disposed of than that required by the state regulations (SIP). These amounts are negligible as compared to the national totals.

Either recycling or landfilling present minimal adverse environmental impact. Totally recycling the solids collected in the control systems has no adverse impact. Landfilling operations must meet the state regulations, thereby minimizing the potential for adverse environmental impact.

7.4 ENERGY IMPACT

The energy impact assessment of the regulatory options and of the SIP provisions consists of determining the numbers of model glass melting furnaces built to produce the amounts of glass listed in Table 7-1 and then calculating the energy required by control systems installed on these new furnaces. Estimating the total energy consumption of all industrial categories for several mixes of installed control equipment provides a range of energy impact for each regulatory option and for the SIP regulations.

Assuming that 26 weight percent of pressed and blown glass is produced in the smaller, 50 TPD furnaces, as estimated from information in NEDS, the integral number of model glass melting furnaces (refer to Table 6-2), on which the energy impact is based, are:[2]

Container Glass	25 Furnaces
Pressed and Blown: Soda-Lime 50 TPD	4 Furnaces
Pressed and Blown: Soda-Lime to 100 TPD	6 Furnaces
Pressed and Blown: Other than Soda-Lime 50 TPD	1 Furnace
Pressed and Blown: Other than Soda-Lime 100 TPD	2 Furnaces
Wool Fiberglass	6 Furnaces
Flat Glass	1 Furnace

Electricity supplies the energy required by the control systems. The major portion of the energy operates fans which maintain the pressure drop across the system. For fabric filter and venturi scrubber systems, the minor amounts of energy used in equipment such as solids conveyors and pumps are negligible as compared to the amount used in powering fans. The power required by the fans is considered to represent the energy impact of these control systems. For electrostatic precipitators, electricity used to charge the plates is added to the fan energy requirements to arrive at the energy impact. As all-electric melting has limited applicability, the energy impact of this control system is not assessed in this section.

The energy requirements for control equipment are extrapolated from published values assuming that the fan power scales with the exhaust flow rate and that the energy to charge the electrostatic precipitator plates scales with the solids collection rate.[5] The energy impacts of each control system, expressed as kWh/kg (Btu/ton) are summarized in Table 7-9. These values represent energy requirements at the glass melting furnace. Utility efficiencies will be accounted for later in this section. Since the pressure drop in fabric filter and venturi scrubber systems remains constant for the regulatory options and the SIP regulations, the assessed energy impact does not vary between them.

The energy requirements for several combinations of control equipment within each glass category provide a range of values of energy impact. The equipment combinations used in the assessment and the energy impacts associated with these combinations are shown in Table 7-10. Again, these values refer to the energy utilized at the glass melting furnaces and do not account for inefficiencies in electricity production. Electrostatic precipitators use the least amount of electricity of any control system and therefore,

Table 7-9. ENERGY REQUIREMENTS FOR CONTROL SYSTEMS

Glass Industry Category	Fabric Filter Satisfying - Option I - Option II - SIP		Venturi Scrubber Satisfying - Option II - SIP		Electrostatic Precipitator					
					Option I		Option II		SIP	
	kWh/kg $x10^{-2}$	(Btu/ton) $x 10^{5}$	kWh/kg $x10^{-2}$	(Btu/ton) $x10^{5}$	kWh/kg $x10^{-3}$	(Btu/ton) $x10^{4}$	kWh/kg $x10^{-3}$	(Btu/ton) $x10^{4}$	kWh/kg $x10^{-3}$	(Btu/ton) $x10^{4}$
Container	4.09	(1.27)	6.42	(1.99)	6.67	(2.07)	6.67	(2.07)	6.58	(2.04)
Pressed and Blown: Soda Lime 50 TPD	5.06	(1.57)	-	-	7.96	(2.47)	7.96	(2.47)	-	-
Pressed and Blown: Soda Lime 100 TPD	5.06	(1.57)	-	-	8.00	(2.48)	7.96	(2.47)	7.96	(2.46)
Pressed and Blown: Other Than Soda Lime 50 TPD	5.06	(1.57)	-	-	8.16	(2.53)	8.12	(2.52)	8.09	(2.51)
Pressed and Blown: Other Than Soda Lime 100 TPD	5.06	(1.57)	-	-	8.38	(2.60)	8.35	(2.59)	1.64	(2.58)
Wool Fiberglass	3.51	(1.09)	-	-	6.51	(2.02)	6.45	(2.00)	6.42	(1.99)
Flat	-	-	-		1.09	(3.37)	1.08	(3.34)	1.07	(3.32)

Table 7-10. CONTROL EQUIPMENT COMBINATIONS AND ENERGY REQUIREMENTS

		Option I		Option II		S I P	
		kWh x 10^6	Btu x 10^9	kWh x 10^6	Btu x 10^9	kWh x 10^6	Btu x 10^9
Container Glass	Case 1 25 Electrostatic Precipitators	12.9	(44.3)	12.9	(44.3)	12.8	(43.6)
	Case 2 20 Electrostatic Precipitators 5 Fabric Filters	26.3	(89.7)	-	-	-	-
	Case 3 18 Electrostatic Precipitators 2 Fabric Filters 5 Venturi Scrubbers	-	-	40.7	(139.)	40.4	(138.)
Pressed and Blown: **Soda Lime** **50 TPD**	Case 1 4 Electrostatic Precipitators	.52	(1.77)	.52	(1.77)	-	-
	Case 2 2 Electrostatic Precipitators 2 Fabric Filters	1.91	(6.51)	1.91	(6.51)	-	-
Pressed and Blown: **Soda Lime** **100 TPD**	Case 1 6 Electrostatic Precipitators	1.48	(5.06)	1.48	(5.04)	1.46	(5.03)
	Case 2 4 Electrostatic Precipitators 2 Fabric Filters	4.10	(14.0)	4.10	(14.0)	4.1	(14.0)
Pressed and Blown: **Other Than Soda** **Lime 50 TPD**	Case 1 1 Electrostatic Precipitator	.15	(.51)	.15	(.51)	.15	(.50)
	Case 2 1 Fabric Filter	.92	(3.15)	.92	(3.15)	.92	(3.15)
Pressed and Blown: **Other Than Soda** **Lime 100 TPD**	Case 1 2 Electrostatic Precipitators	.43	(1.48)	.43	(1.48)	.43	(1.47)
	Case 2 2 Fabric Filters	2.63	(8.96)	2.63	(8.96)	2.63	(8.96)
Wool Fiberglass	Case 1 6 Electrostatic Precipitators	2.35	(8.02)	2.33	(7.94)	2.31	(7.90)
	Case 2 3 Electrostatic Precipitators 3 Fabric Filters	7.50	(25.6)	7.50	(25.6)	7.50	(25.6)
	Case 3 6 Fabric Filters	18.3	(62.3)	18.3	(62.3)	18.3	(62.3)
Flat Glass	Case 1 1 Electrostatic Precipitator	2.61	(8.92)	2.59	(8.84)	2.57	(8.78)

represent miminum energy impact. The container glass equipment combination of fabric filters and venturi scrubbers are chosen to reflect an approximation of the currently operating mix of control equipment. As discussed previously, venturi scrubber systems cannot be installed to meet Option I. Uncontrolled glass melting furnaces in the Pressed and Blown: soda-lime (50 TPD) meet SIP provisions.

Summing the energy consumption over the industrial categories yields the energy impact range for each regulatory option and for the SIP regulations. Implementing Option I requires from 20.4 x 10^6 to 56.8 x 10^6 kWh (70.1 x 10^9 to 193.5 x 10^9 Btu) at the glass melting furnace. Assuming a utility efficiency expressed as 10,000 Btu/kWh required for 3,400 Btu/kWh (34 percent) and a heat content of a barrel of oil of 6.023 x 10^6 Btu, the impact of Option I on electrical utilities ranges from 60.0 x 10^6 to 167.1 x 10^6 kWh (206.2 x 10^9 to 569.1 x 10^9 Btu) which is equivalent to 34,200 to 94,000 barrels of oil. Implementing Option II requires 20.4 x 10^6 to 71.2 x 10^6 kWh (69.9 x 10^9 to 242.8 x 10^9 Btu) at the glass plants corresponding to a demand on utilities of 60.0 x 10^6 to 209.4 x 10^6 kWh (205.6 x 10^9 to 714.1 x 10^9 Btu) or 34,100 to 118,600 barrels of oil. Similarly, the SIP provisions require 19.7 x 10^6 to 68.9 x 10^6 kWh (67.3 x 10^9 to 235.2 x 10^9 Btu) provided to the glass plants, which translates to 57.9 x 10^6 to 202.6 x 10^6 kWh (197.9 x 10^9 to 691.8 x 10^9 Btu or 32,900 to 114,900 barrels of oil.

Because total energy requirements depend more on the types of control systems selected than on the degree of emission reduction achieved, the ranges of energy impacts of the regulatory options and the SIP regulations overlap making comparisons between them unquantifiable. However, two conclusions are apparent. In general, meeting the SIP provisions will require less energy than the furnaces classified in the Pressed and Blown: soda-lime subcategory. Also, increasing the use of venturi scrubber systems increases the energy impact of Option II and the SIP provisions.

Although no comparisons are made between the ranges of energy impact of the regulatory options and the SIP provisions, these energy ranges can be compared to the energy required to produce glass. Using published values for the Container Glass, Flat Glass, and Pressed and Blown Glass Standard Industrial Classifications, the energy requried to operate control systems for these classifications ranges from 0.2 to 2 percent, 0.2 percent, and from 0.1 to 0.5 percent of the energy needed to produce glass, respectively.[6]

8.0 ECONOMIC IMPACT

Chapter 8 contains four sections. In Section 8.1, the role of the glass industry in the U.S. economy and the structure of the industry are described. The four segments of the glass industry -- Flat Glass, Container Glass, Wool Fiberglass, and Pressed and Blown Glass -- are identified and characterized. Textile Fiberglass, a sector of the Pressed and Blown segment, was considered sufficiently large to identify and characterize as a fifth segment. Several aspects of each segment are discussed: geographic distribution, integration and concentration, import/export considerations, demand determinants, supply considerations, and estimations of new sources.

In the Section 8.2, installed capital cost and annualized costs for control of particulate emissions from new glass furnaces have been estimated for 27 combinations of model plant size, control option, and industry segment.

Section 8.3 describes briefly other cost considerations and their impact on the economic analysis of particulate emission control systems.

Section 8.4 contains an analysis of the economic effect of imposing NSPS controls on furnaces within new primary glass plants. It was hypothesized that no adverse effects on new plant construction would result. The hypothesis was supported by the findings of the analysis, which indicate that imposition of NSPS controls will not impact significantly on a new grassroots primary glass manufacturing plant investment decisions. It may therefore be concluded that construction of new plants should not be impeded.

8.1 INDUSTRY ECONOMIC PROFILE

8.1.1 Introduction

Glass making is one of the oldest industries, and generations of glass makers have practiced and revised this craft. It is now an industry that is highly sophisticated, still improving technologically, diverse, and essential to the quality of life. Several firms in the glass industry are numbered among the giants in business and industry internationally. As such, they are essential to both domestic and world economy. Their contribution to medical research, protection of the environment, and engineering technology have made essential contributions to everyone's well-being and comfort.

The scope of the industry still provides room for the artist who forms dreams in glass to be shared with those who value creativity and craftsmanship. It includes the tough spirit of the entrepreneuer who has found a way to make our free-enterprise system work in a nation of big business.

As might be anticipated with an industry so large and of such longstanding, the diversity of its products and enterprises cannot be fully assessed. While large firms in the industry are publicly held, many of the firms are small and privately held. Public reporting is not always disaggregated in such a way that it contains the researcher's desired specificity. Privately-held firms report nothing publicly, and industry experts and representatives become the source of reportable data.

This study attempts to assess the economic impact of NSPS on the primary glass manufacturers within the glass industry. This part profiles the overall industry.

The following order for the study was selected: (1) Flat Glass, (2) Container Glass, (3) Wool Fiberglass, (4) Textile Fiberglass, and (5) Pressed and Blown glassware. The study recognizes that textile fiberglass is identified as one sector of the pressed and blown segment. It was judged to be of sufficient magnitude to justify inclusion in the study as a separate consideration.

8.1.2 FLAT GLASS

8.1.2.1 Geographic Location

The 27 primary manufacturing plants now operating in the domestic flat glass industry are located in 14 different states, which range across the entire country. There are 4 plants in the state of Pennsylvania, and 3 plants each in the states of California, Tennessee, and West Virginia. A fourth plant is under construction in California and is expected to become operative in third-quarter 1978.

Traditionally, the primary criterion for plant location has been proximity to raw material sources. However, the plant currently being constructed in California was apparently placed there to take advantage of the growing market in the Western states.[1]

8.1.2.2 Concentration

The U.S. flat glass industry is highly concentrated, with only 7 companies participating in the primary manufacturing sector: PPG Industries, Inc.; Libbey-Owens-Ford Co. (LOF); Ford Motor Co., Glass Division; Guardian Industries Corp.; ASG Industries, Inc.; C-E Glass Division of Combustion

Engineering, Inc.; and Fourco Glass Co. The four largest companies, PPG, LOF, Ford, and Guardian, controlled 86.7% of total domestic production capacity in 1977.[2] PPG dominates the construction market and Libbey-Owens-Ford dominates the automotive market.

The Justice Department filed a civil antitrust suit on May 10, 1978, challenging the proposed acquisition of the Glass Division of Combustion Engineering, Inc. by Guardian Industries Corp., alleging that the proposed acquisition would eliminate competition between the companies in the manufacture and sale of flat glass and would increase concentration in the U.S. flat glass industry.[3]

8.1.2.3 Integration

The companies engaged in the primary manufacture of flat glass also further process the glass by tempering and/or laminating. In most cases, these companies fabricate a number of flat glass products for the construction and automotive markets.

In addition, four of the seven companies also manufacture products unrelated to flat glass and flat glass products. Ford manufactures automobiles and light trucks, tractor parts and components, and communication and electronics systems. PPG manufactures textile fiberglass, chemical coatings and resins. Combustion Engineering designs, manufactures, installs, and services steam generating equipment for the electric utility industry, provides design engineering, and construction services for the chemical, petrochemical and petroleum industries, and provides equipment, products and services to other industrial markets. Guardian is engaged in photo processing activities and the manufacture and marketing of insulation materials.

Vertical integration in the industry includes the mining and processing of raw materials. Captive distributorships and captive markets are other characterstics of certain segments of the industry.

8.1.2.4 Import and Export Considerations

In the late 60's, foreign imports of flat glass offered severe competition to domestic products, particularly in the sheet glass market. At the instigation of members of the flat glass industry, the tariff rate reductions stemming from the 1967 General Agreement on Tariff and Trade were re-examined. The ultimate result was the restoration in 1970 of higher tariff rates on sheet glass imports.

The year 1974 was the turning point in the flow of flat glass imports, and from 1974 through 1978, the balance of trade remained consistently favorable to the U.S. During 1978, the rate of growth for imports is expected to surpass the rate of growth for exports, but the balance of trade is expected to remain favorable to the U.S.[4] The principal market for flat glass exports is Canada, which is also the principal supplier of flat glass imports. Imports and exports to and from Canada in 1976 totaled \$26 million and \$72 million, respectively.

8.1.2.5 Demand Determinants

Demand within the flat glass industry is derived primarily from the automotive market and the residential and non-residential new construction market. Demand, therefore, fluctuates in accordance with the economic activity of these two industries. Historically, flat glass shipments tracked the 1974-1975 downswing into the 1976-1977 upswing in the automotive and construction industries rather closely. Current flat glass industry forecasts are based largely on expected new car and new construction demand, with the outlook for 1978 being favorable; flat glass product shipments for 1978 have been predicted to reach $1.98 billion, a gain of 8.5% over 1977.[5]

A third major industry from which flat glass demand is derived is the secondary construction market (repair and remodeling), which one industry representative has decribed as "a very important source of glass demand (which) acts as a smoothing influence on the fluctuating automotive and construction markets".[6]

Demand is also influenced by federal and state regulations. The Consumer Safety Product Commissions Standard 16 CFR 1201 (Safety Standard for Architectural Glazing Materials) became effective July 6, 1977. This Standard requires all glazing materials used in high traffic areas of both public and private buildings, including private homes, to be impact resistant as defined in the provisions of the Standard. Although some delays have occurred in fully implementing the Standard, it is expected to significantly influence the demand for tempered and laminated glass.

Even more significant from the viewpoint of overall demand for flat glass is the fact that a number of states have already adopted energy-efficient building code standards that call for double glazing in areas having cold climates. Not only is this concept of double glazing expanding into warmer climates as a method of saving cooling energy, but the concept of triple glazing is also gaining favor in residential remodeling projects.

Other demand-creating developments in the energy conservation area are solar daylighting and heating systems and retrofit glazing systems, which add a second panel of glass to existing single-glass windows in commercial buildings.

On the other side of the demand ledger is a continuing trend toward the use of thinner glazing materials in the construction industry and thinner windshields and side and rear windows in the automotive industry. The action of many insurance companies in removing windshield and other car glass from comprehensive coverage, and in instituting $50/$100 deductible provisions is also expected to have an adverse effect on automotive glass sales unless the industry can develop successful counter-measures.[7] A possible offsetting factor, however, is that there are nearly 130 million vehicles traveling American roads this year, a 20% increase over the second largest windshield replacement year of 1973.[8]

Similarly, any lessening of demand for glass in the automotive industry caused by the downsizing of cars is expected to be offset by compensating changes in car design and by the demand created by the trend toward customizing recreational vehicles.

In each of the markets discussed above, there appears to be no readily available substitute for glass. In a few rather limited applications, plastic may be substituted, e.g., in solar applications. Intra-industry, qualities of glaze or lamination may substitute for one another in use, but not in price. Demand, then, becomes a matter of consumer taste in a price-sensitive market.

8.1.2.6 Supply Considerations

Estimated capacity for each of the 27 primary manufacturing plants now operating in the domestic flat glass industry is shown in Table 8-1.

Flat glass production in 1977 was 2,594,000 tons.[9] From 1972 to 1976, quantity shipments of float, plate and sheet glass grew at an average annual rate of only 2%, but the real growth of flat glass product shipments is expected to maintain a compound annual growth of 4.2% for the next 5 years.[10]

Industry representatives have indicated that the flat glass industry operated at close to full capacity in 1977 with industry capacity being somewhat reduced, however, by the unusual amount of downtime and plant closings attributable to industry upgrading.[11] The past few years have been a period of technological change for the flat glass industry, as sheet glass and plate glass production were phased out in favor of more efficient float glass production. An example of this kind of changeover is Guardian's new float glass plant in Kingsburg, California which is intended to replace unprofitable sheet glass plants and is expected to increase the company's glass-making capacity by more than 50%.

The distribution of projected capacity growth between new and existing plants is unkown. However, on the basis of 1977 production and current estimated growth, if a worst-case scenario is assumed, where all additional capacity must come from new plants, the equivalent of two new plants will be needed to meet projected growth and capacity considerations through 1982.

Table 8-1

FLAT GLASS PLANTS

Producer	Plant Location	Capacity
PPG Industries, Inc.	Fresno, California	400 TPD
	Mt. Zion, Illinois	450 TPD *
	Cumberland, Maryland	400 TPD
	Crystal City, Missouri	400 TPD
	Carlisle, Pennsylvania	900 TPD
	Meadville, Pennsylvania	800 TPD
	Wichita Falls, Texas	1,000 TPD
Libbey-Owens-Ford Co.	Ottawa, Illinois	400 TPD
	Lathrop, California	450 TPD
	Laurenburg, North Carolina	750 TPD
	Rossford, Ohio	1,000 TPD
	Toledo, Ohio	450 TPD
Ford Motor Company, Glass Division	Dearborn, Michigan	400 TPD
	Tulsa, Oklahoma	1,000 TPD
	Nashville, Tennessee	1,500 TPD
Guardian	Carleton, Michigan	900 TPD
ASG Industries, Inc.	Jeannette, Pennsylvania	270 TPD *
	Greenland, Tennessee	900 TPD *
	Kingsport, Tennessee	385 TPD *
C.E. Glass Division of Combustion Engineering, Inc.	Floreffe, Pennsylvania	400 TPD
	Fullerton, California	70 TPD *
	St. Louis, Missouri	195 TPD *
	Cinnaminson, New Jersey	500 TPD
Fourco Glass Co.	Fort Smith, Arkansas	225 TPD *
	Clarksburg, West Virginia	200 TPD *
	Bridgeport, West Virginia	450 TPD

*These estimates represent reported sheet, plate, and/or rolled glass capacity; other estimates are measures of float capacity.

Source: Source Assessment: Flat Glass Manufacturing, U.S. Environmental Protection Agency

8.1.3 CONTAINER GLASS

8.1.3.1 Geographic Location

Container Glass manufacturing plants are placed as close as possible to the markets they are intended to serve and plants are sometimes dedicated almost entirely to servicing the needs of one nearby customer. In 1977, there were 123 container glass manufacturing plants located in 30 states were identified. Clustering occurred on both the East and West Coasts, in the North Central industrial states and, to a somewhat lesser extent, in the South, which appears to be the fastest growing area.

8.1.3.2 Concentration/Integration

The high degree of concentration in the container glass industry is evidenced by the fact that the four largest container glass companies are currently reported as accounting for 56% of product sales, with the next four largest companies accounting for an additional 21%.[12]

In 1976, Owens-Illinois, Inc., was reported to have a 28.9% share of the container glass market, with Brockway Company, Inc. having the next largest share, 11.4%.[13] Other companies ranking among the first 10 in 1976 market share included: Anchor Hocking, Thatcher Glass, Glass Containers Corp., Kerr Glass, Indian Head, Ball Corp., Chattanooga Glass, and Midland Glass.

The major firms in the industry are highly integrated, multi-product manufacturers. These firms have substantial non-container volume in the

United States, significant foreign operations, or both. Container glass is distributed by contract with other companies who, in turn, use it to package their products. Design and styling capability exists in each major firm for the introduction of new shapes and forms of container glass.

8.1.3.3 Import/Export Considerations

There is relatively little export activity in the container glass industry -- only about 1% of annual total value of product shipments ($33.1 million in 1976)[14] is accounted for in this manner. Import activity is even more limited, with imports having less than 1% share of the domestic market. In both instances, foreign trade is considered economically unfeasible because of high transportation costs and the easy availability of similar products from local resources.

The major markets for U.S. exports are Canada, Venezuela, Australia, and the United Kingdom. Major suppliers of imports are France, Italy, Canada, and Mexico. Mainland shipments of container glass to Puerto Rico, although not considered exports, are worthy of mention because of their relative magnitude, $19.4 million in 1976.[15]

The tariff rates currently in effect on imports to the U.S. are the end result of a number of successive reductions carried out under the provisions of the 1967 General Agreement on Tariff and Trade.

8.1.3.4 Demand Determinants

Glass is one of the earliest and most universally accepted packaging materials. It competes in the market with other packaging materials, particularly plastics and metal. The market shares shown in Table 8-2 indicate that the market share for glass has remained relatively stable from 1970 to 1976, and is projected to remain at that level through 1980. The demand for metal cans has also remained relatively even, with a slight gain projected for 1980. Share of market for plastics, however, has grown about 30% in the 1970-76 period, with a much slower rate predicted in the future.

Container glass demand is derived primarily from three major market segments: food, beer, and soft drinks. Wines and liquors have a lesser share of market, and relatively minor segments of the market include toiletries and cosmetics, household and industrial chemicals, and drugs, medicinal, and health containers.

The beer market, where glass competes only with metal cans, has been the major area of growth for container glass over the past 10 years, with an annual growth rate of over 7.5%.[16] Shipments of non-returnable beer bottles, which account for more than 95%[17] of total beer bottle shipments, are responsible in large measure for this gain. The popularity of this type of container is expected to result in continuing gains unless restrictive legislation is enacted on a wide scale. Non-returnable glass bottles have a held a significant cost advantage over metal cans since 1975, when can prices rose sharply. In 1977, this price differential disappeared as the container glass industry was impacted by rising fuel and labor costs. However, it appears that container glass may again gain a significant price advantage over metal cans as the rising costs of steel and aluminum are fully passed on to the can companies. Prices of container glass are expected to be lower at the end of 1979 than they have been at any year-end since 1967.[18]

Table 8-2

SHARE OF TOTAL PACKAGING MARKET

	1961	1970	1976	1980
Paperboard	37.9	34.0	33.5	31.5
Metals	25.0	27.8	27.5	29.2
Plastics	5.3	9.1	12.0	13.1
Paper	15.6	13.7	11.9	11.5
Glass	8.6	9.8	9.8	9.8
Wood	4.5	3.8	3.6	3.5
Textile	2.5	1.5	1.2	1.0

Source: American Glass Review, May, 1977, p. 12.

Plastic bottles are not expected to impact on the beer industry very soon because of the problems inherent in the chemical composition of the plastics that can be used for these purposes.

In the soft drink market, contianer glass competes with both metal cans and plastics. Glass shipments for the soft drink industry grew explosively in the period between 1960 and 1970. Thereafter, container glass lost market share rapidly. However, after a gain of only 1% in 1976, container glass shipments to the soft drink industry rose by 4% in 1977.[19] It is anticipated that this sector will remain a source of growth for container glass over the next few years. The major competitors to container glass in this market are metal cans, but plastic containers are making some inroads in the area of larger-sized soft drink bottles, chiefly in the 32-ounce and over sizes, which are cost competitive with glass and metal containers.

Prices of smaller-sized plastic bottles are still higher than those for a comparable glass product. Plastic containers currently hold less than 1% of this market. However, the weight advantage of plastic containers over container glass, coupled with expected reduction in production costs in next few years, will probably result in a market share of 5-10% by the early 1980's[20] unless legal restrictions against plastic containers are enacted.

The food industry continues to be the largest single user of container glass, although there has been little growth in demand for this market in recent years, and shipments were down by about 1% in 1977. This downward trend apparently reflects the lack of growth in the food industry itself, coupled with increasing competition from plastic containers.

In the wine and liquor segment of the beverage market shipments of liquor bottles rose about 12% in 1977, after declining 3% in 1976. Wine bottle shipments rose about 4% after a 3% drop in 1976. This reflects a trend toward larger-sized bottles in recent years, which is currently being reversed by the switch-over to metric sizes that is required to be implemented in full by January 1, 1980. Unit volume shipments should rise as the number of containers required to package the same gallonage increases.

Container glass in other markets, lost ground moderately in 1974 and 1975, showed a sharp increase in 1976, and settled back to a modest gain in 1977.

Demand determinants other than price and the availability of close substitutes include a number of functional qualities that are either not possessed by competing metal and plastic containers or are possessed in a lesser degree. Chief among these qualities are resealability, inertness, and reusability. Resealability is a desired characteristic in all segments of the container glass market, because it helps to maintain the freshness and quality of the container's contents and because it prevents or retards spoilage and contamination. Among container materials, glass is uniquely inert. Consequently, it can be used to package materials that might react dangerously or unpleasantly with plastics or metals. Reusability, defined as both refillability and returnability, is particularly important in the beverage segment of the market. A number of legislative actions are currently pending which may make reusability mandatory. At the present time, only container glass meets the requirements.

Other important demand determinants are taste, disposable personal income, population, and age. The influence of taste as a determinant is evident as the aesthetic appeal of glass, with its highly visible clarity and purity, is translated into market appeal at the shelf level, particularly in the food, cosmetic, and wine segments of the market.

Rising disposable personal income impacts the container glass industry favorably in several markets. Toiletries, cosmetics, wines, and liquors are non-essential goods that react strongly to gains and losses in personal disposable income. As a complementary good, the demand for container glass associated with these items fluctuates accordingly. Although demand in these segments of the market decreases as personal disposable income decreases, another segment of the market picks up some of the slack -- containers for food items that are packaged for use at home and home canning jars and bottles exhibit a minor degree of compensatory gains.

Population growth is a self-evident determinant of demand for container glass, particularly in the food and beverage segments of the market. Here, too, age is a determinant of demand as it controls the proportions of the consumer population that are included in the groups eating baby food or drinking soda, beer, wine, or liquor.

In addition to these primary determinants of demand, there are a number of secondary forces that, empirically, have influenced demand in certain segments of the market. These include such events as bad weather, crop failures strikes, rising raw material costs, and energy shortages.

Finally, there is another powerful force operating in the marketplace that is unique to the industry - the Glass Packaging Institute. This trade association is active, well-organized, articulate, and influential. Among its many activities is involvement in major consumer TV and trade advertising, market research and public relations programs. The stated objectives of these programs being "to increase preference for glass packaging among prime influencers in the trade and among consumers and to give the container glass industry an aggressive, positive and socially conscious image among its members and "the public".[21]

8.1.3.5 Supply Considerations

In 1977, production of container glass amounted to 303.5 million gross units, and domestic shipments were 307.8 million gross units, valued at $3,674.8 million.[22]

The average annual growth rate in unit volume was 2.2% for the period between 1971 and 1975. In 1975 and 1976 growth rates were 5% and 3%, respectively. Growth is expected to continue at a real annual compound rate of 2.3% between now and 1982, with shipments reaching 340 million gross by 1982.[23]

Severe cost pressures were evident in the industry in 1977. The glass industry is highly labor intensive, and labor costs represent about a third of total costs. A front-end-loaded labor contract negotiated with the unions in 1977 resulted in a 13% increase in labor costs for the year. Energy, which accounts for about 9% of glass industry costs, rose 20-25%.[24]

The desire of container glass manufacturers to relocate production facilities closer to customers (for example, breweries) led to a wave of expansion in the years 1972-1977. Industry analysts estimate that the industry is now operating at about 91-92% of practical capacity and has not worked at full practical capacity for a number of years. This, taken in conjunction with the trend toward mandatory deposit laws, the inroads being made by plastics in some areas, and the trend toward lighter-weight bottles leads these analysts to believe that no new expansion or construction of new facilities will be undertaken in the near future, except by self-manufacturers.[25]

The capacity of a typical new container glass plant has been specified by industry representatives to be 500 TPD. The three new plants that are currently under construction and the expansions already underway may result in significant excess capacity if demand is less than anticipated. However, 1977 capacity equated with 1977 shipments of 307.8 million gross units and with 1982 shipments projected at 340 million gross units, the equivalent of seven additional new plants would be needed if a "worst-case" situation existed and all additional required capacity had to be met by new plants.*

8.1.4 WOOL FIBERGLASS

8.1.4.1 Geographic Location

Wool fiberglass is manufactured in 20 plants in 10 different states. Five additional plants are used by one manufacturer to further fabricate its product lines, a process that the other manufacturers incorporate in their manufacturing plants.

Most of the industry's plants are located in the Eastern half of the United States, but there are 4 plants in the Central states and 2 on the West Coast. It is the practice in the industry to locate plants near major population centers in order to insure the availability of an adequate labor force and to take advantage of the variety of transportation needs offered in urban areas.

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*This estimate assumes that 23.6 gross units = 1 ton, based on the average-weight container in 1977.

8.1.4.2 Concentration and Integration

There are only 3 firms operating in the major markets of the wool fiberglass industry, with 1 new firm currently operating on the periphery of the market. Owens-Corning Fiberglass, Inc. is the acknowledged industry leader, claiming 50% of market share. Certain-Teed Products Corp. and Johns-Manville Corp. split the remaining market share in almost equal proportion.[26] These three are large companies with integrated multi-product lines.

The industry is oligopolistic in structure, with no small regional producers. Economies of scale are important and a large capital investment is required for successful entry into the industry. The German firm of Knauf, which recently became the 4th member of the industry, did so by purchasing a high-density insulation plant in Indiana from Certain-Teed. The plant was available only because Certain-Teed had been ordered to divest itself of the facility by the courts at the instigation of the Federal Trade Commission, which currently has the industry under scrutiny.[27]

8.1.4.3 Import/Export Consideration

International trade is not an important factor in the wool fiberglass industry. Exports represent a very small percentage of total shipments, with Canada being the primary market. Imports do not provide any competition for domestic manufacturers.

8.1.4.4 Demand Determinants

Wool fiberglass is used primarily as building insulation and also in acoustical ceiling tiles, heating and cooling pipe and duct insulation, and in process equipment and appliance insulation.

Wool fiberglass has captured about 52% of the total insulation market, and accounts for more than half of all residential insulation sales. Its main competition can be broken down as follows. (1) Mineral wool, the principal residential insulation material until fiberglass emerged in the 1950's. Mineral wool carries the advantage at high temperatures since fiberglass breaks down at more than 450°F. Mineral wool maintains a 12% share of the housing area, but has been used more extensively in nonresidential markets. (2) Cellulose, a macerated paper product, has grown explosively in the market in the past two years because of the increasing unavailability of fiberglass in many areas, and because of the extreme ease of entry into and the high returns of the cellulose business. (3) Polyurethane and urea-formaldehyde foams, still not cost-competitive with fiberglass, are finding increased use in the building markets.

Generally speaking, the demand for wool fiberglass as an insulating material is related to its price competitiveness with other products, the ease with which it can be handled and installed, and the fact that space is not a constraining factor in ceiling and floor areas. While supply has tightened, so that its share of the various markets has fallen somewhat, it is expected to maintain the status quo in most areas.

In residential construction, new housing continues to be the largest source of demand for structural insulation. Forecasts of demand are based upon expansion of housing starts, amount of insulation used per unit, and change in the housing mix.

Mobile homes also provide a growing market for insulation. Though mobile home shipments remain well below peak levels of 1972-1973, the demand for insulation has been stimulated by rapid increases in per-unit use.

Residential retrofit remodeling is another significant source of demand. Attempts to measure the number of housing units in this country which are insufficiently insulated yield a figure of 24.0 million to 27.2 million. Reinsulation activity seems to be accelerating, and incentives to reinsulate should continue to be compelling during the next several years.

In the non-residential market, wool fiberglass maintains a relatively small share where it faces competition from wood fiberboard, tectum, gypsum, perlite board, foam glass, and ceramic insulation material. Heavy density wool fiberglass holds approximately 50% of the appliance insulation market, where it competes with mineral wool in situations of intense heat and with foam and foam board in cold appliances. In pipe insulation, a growing market in recent years, wool fiberglass is the preferred insulating material for fluid-carry systems of 0 to 450°F.

In air-handling, rigid fiberglass ductwork has been consistently capturing a sizeable market share from galvanized steel. As an insulator, it retains heat and cold and does not "sweat". It retains approximately one-third of the ceiling board and tile market, where it competes with gypsum, foam board, cork and wool fiber board. In nonresidential roof insulation, Owens-Corning, the only firm that produces it, competes with a wide range of foams and expanded minerals.

8.1.4.5 Supply Considerations

Estimated capacity for the wool fiberglass industry in 1977 was 1,443,000 tons, 98.8% of which was utilized in producing shipments of 1,425,000 tons[28] (see Table 8-3). This total was 43% greater than shipments for 1976. Industry analysts indicate that volume of shipments will peak in 1978, decline in 1979 as new single-family housing construction declines, and stabilize at approximately a 6% growth rate for the industry between 1979 and 1982.[29]

Certain-Teed is building a new plant in Chowchilla, California and production is scheduled to begin in 1979. No plans for new facilities have been announced by any company beyond 1979. Consistent with industry projections, it appears that increases in demand will be met by existing facilities. The industry has demonstrated the ability to increase production by 4 to 5% a year through furnace rebuild.[30] Announced new capacity plus industry expansion is estimated to be sufficient to meet consumer demand in 1982.

However, for purposes of this study, and in order to present a worst-case analysis, it is assumed that all additional required capacity

Table 8-3

SHIPMENTS OF WOOL FIBERGLASS

	Structural Insulation			Other Insulation			Total Insulation		
	Shipments (Mil. lb.)	Value ($ mil.)	Apparent Value/lb.	Shipments (Mil. lb.)	Value ($ mil.)	Apparent Value/lb.	Shipments (Mil. lb.)	Value ($ mil.)	Apparent Value/lb.
1965	438	$ 92.5	$.211	608	$157.9	$.260	1046	$250.5	$.239
1966	462	104.8	.227	613	177.3	.289	1076	282.1	.262
1967	483	108.8	.225	554	170.5	.308	1038	279.3	.269
1968	567	133.0	.235	557	179.0	.321	1124	312.0	.278
1969	627	157.6	.251	576	197.6	.343	1203	355.2	.295
1970	645	165.6	.257	541	190.2	.352	1186	355.8	.300
1971	880	218.2	.245	627	207.1	.330	1517	425.3	.280
1972	1055	267.7	.254	683	219.4	.321	1738	487.1	.280
1973	1179	309.5	.263	725	249.3	.344	1904	558.8	.293
1974	1162	339.8	.292	781	310.2	.397	1943	650.0	.335
1975	1103	381.5	.346	572	294.1	.514	1675	675.6	.403
1976	1384	471.8	.341	608	345.6	.568	1992	817.4	.410
1977E	2100	798.0	.380	750	465.0	.620	2850	1263.0	.443
Compound Growth Rates									
Least Squares:									
1965-77	12.0%	16.8%	4.5%	2.1%	8.4%	6.1%	7.9%	12.8%	4.7%
1970-77	12.8	19.7	6.6	2.6	13.1	9.9	8.6	16.2	7.1

Source: Commerce Department, Merrill Lynch estimates.

will be met by new facilities. Industry representatives indicate that typical new facilities will produce 200 tpd. The equivalent of seven new facilities will be required in addition to the new facility currently under construction in California in order to meet projected demand through 1982.

8.1.5 TEXTILE FIBERGLASS

8.1.5.1 Geographic Location

Textile fiberglass is produced by 6 firms in 16 plants in 7 states in the United States. Three plants are located on the West Coast, 2 are located in Texas, and the remaining plants are in the eastern portion of the country. A high concentration of plants is apparent in North and South Carolina and Tennessee where nearly half of the existing facilities are located. Announced plans for new facilities indicate that the South-Central portion of the country will be developed next for the industry's market.

8.1.5.2 Concentration and Integration

The textile fiberglass industry is highly concentrated, with three major firms dominating the industry: Owens-Corning with 58% of the capacity in the industry; PPG Industries, 31%; and Certain-Teed, 6%. The remaining 5% of industry capacity is shared by Johns-Manville, Reichold Chemical, and

United Merchants. With the exception of the latter two firms, the remaining firms produce textile fiberglass as a part or division of a multi-product integrated product line. Owens-Corning is the leader in the textile industry, with PPG Industries is the leader in flat glass, with fiberglass as a secondary line of production. Both Certain-Teed and Johns-Manville are integrated producers of building materials. Certain-Teed has served the textile fiberglass market with fiberglass yarn imported from Japan, but will soon commence U.S. production for a fully integrated product line.

The textile fiberglass industry is only 40 years old. It was eleven years after Owens-Corning introduced the product before a second firm entered the industry. Capital investment requirements for entry into the industry are large and have precluded the entry of many small firms. Similarly, few firms have the capital required to engage in the extensive research and development activities necessary to exploit this market. In primary end-product usage, textile fiberglass competes in a market dominated by the aluminum and steel industries, two of the largest and oldest industries in the nation. Costs associated with the marketing of a relatively new product in an old and entrenched market area, in and of themselves, are sufficient to preclude the entry of small firms into the industry.

8.1.5.3 Import/Export Considerations

At present, no product with the same properties as textile fiberglass is imported into the U.S. Imports of textile fiberglass, mostly from Japan, are small. Certain-Teed has been a major importer, but it is anticipated that Certain-Teed's volume of imports will decrease as its new domestic facility comes on stream.

Only a small percentage of domestically produced textile fiberglass is exported by multi-national firms in order to strengthen the existing markets of foreign subsidiaries or to assist them in the development of new foreign markets. International affiliates of Owens-Corning and PPG Industries service the European market.

8.1.5.4 Demand Determinants

The major end uses of textile fiberglass materials are fiberglass-reinforced plastic (FRP), tire cord, and decorative and commercial fabrics. These account for 94% of the textile fiberglass market, FRP being the major end-product.[31] Other, less extensive, end-uses are electrical wiring and applicances, and paper and tape reinforcement.

As a fibrous reinforcement for plastic, fiberglass presently competes with only aramid and carbon, which have the capability of producing exceptionally hard composites, but which are several times more expensive.

Generally, at the present time, FRP has distinct advantages over its competitors, for example steel and aluminum. FRP can be just as strong as steel, and is usually less expensive on a usage basis, though more costly per pound. It is lighter in weight, and can result in weight savings of up to

50%. FRP usually requires less total energy for production than similar items made of metal, because it offers significant opportunities for molded parts consolidation.

At present, FRP competes with aluminum and steel in the transportation market, with 60% of production going to the automotive sector. Its advantages are: equal strength and durability, opportunity for parts consolidation, resultant savings in cost and energy, and corrosion resistance. The most important current advantage, however, is the savings which it affords in weight. Government regulations regarding fuel economy have made lighter-weight materials most valuable in the production of automobiles and trucks. It is anticipated that this market for FRP will evidence significant growth in the near future.

The marine sector of the transportation market has always been a significant one for FRP. Until 1976, it represented FRP's largest market; it continues to account for 70% of all hulls and decks produced for pleasure boats. FRP's attractiveness is due to its moldability, seamless construction, durability, resistance to corrosion, rust, and rot. It has been estimated that the use of FRP in marine construction resulted in an 80% maintenance saving, in comparison to wood and steel. Experimentation with the production of large ocean-going vessels may influence demand for the product upward.

FRP has many uses in other areas of construction. One such area, the corrosion-resistant segment, should be the most rapidly growing FRP end-market during the next several years. FRP does not corrode, rust, absorb moisture, or conduct electricity. FRP is being increasingly used for pipes in chemical and other process industries that have corrosive environments, as well as for fluid transmission and sewer-water systems applications. FRP pipe costs the same as ductible iron pipe, but more than pipe of concrete, asbestos-cement, and steel. However, FRP pipe is easier to install, because of its lighter weight, and is more durable.

Underground and aboveground tanks constitute about 20% of the non-corrosive products sector. Although the initial installation of an FRP tank can be more costly than one of steel, on a life-cycle basis, FRP is considerably less expensive.

Other end markets of FRP include electrical insulators, electrical apparatus, sports equipment, power tool housings, airplane stabilizers, ladders, and so forth.

Non-FRP textile fiberglass uses include tire cord and decorative fabrics, and commerical industrial applications.

The market for tire cord is shared by fiberglass, steel, and nylon. Textile fiberglass competes with steel in the radial tire sector and with nylon in the bias-belted sector. Although fiberglass radials are less expensive, slightly lighter in weight, and offer better fuel performance because of lower rolling resistance, steel radials continue to hold the largest share of the original equipment market. Fiberglass tires hold only 15% to 20% of the tire replacement sector, which is twice as large as the original equipment sector.

In the decorative and commercial fabrics market, textile fiberglass competes with a variety of synthetic yarn, especially the polyesters. The upholstery market has not developed significantly, and the curtain-drapery market has been impacted by synthetics.

Solid cyclical growth is expected in industrial and commercial applications. Fiberglass has most recently replaced cotton in wire insulation because of its ability to withstand higher temperatures. Fiberglass also is beginning to be used as a cement and concrete reenforcement, although asbestos fiber retains clear price advantages in this area. Another emerging market for textile fiberglass is as mat material for residential roofing, because of its durability and fire resistance, and because asphalt requirements can be reduced by about 25%.

The unique properties of textile fiberglass are only beginning to emerge. Only in the past ten years have engineering and technology advanced to the point where highly sophisticated and intricate products can be expected to grow with technological advances and with the new product development that results.

8.1.5.5 Supply Considerations

Estimated capacity in the textile fiberglass industry in 1977 was 475,000 tons. In the same year, shipments totalled 420,000 tons, utilizing 88.4% of industry capacity.[32]

Table 8-4 suggests an increase in volume shipped, between 1976 and 1977, of approximately 15%. Analysts for the industry predict an increase in volume shipped in 1978 and a decline in 1979. However, average annual growth rate, between 1971 and 1982 is estimated at 9%. FRP is anticipated to account for approximately 81% of total textile fiberglass shipments by 1982.[33]

Owens-Corning and Certain-Teed have announced new facilities in Texas which will become fully operative at the end of 1979.[34] At full operation, the Owens-Corning plant will have production capacity of 100

Table 8-4

SHIPMENTS OF TEXTILE FIBERGLASS

	Shipments (mil. lb.)	Value ($ mil.)	Apparent Value/lb.
1965	287	$128.0	$.446
1966	323	149.8	.464
1967	309	137.5	.445
1968	394	173.1	.439
1969	477	227.4	.477
1970	433	192.7	.445
1971	478	214.6	.449
1972	575	256.9	.447
1973	695	304.2	.438
1974	662	315.9	.447
1975	547	288.1	.527
1976	728	399.6	.549
1977E.	840	500.6	.596
Compound Growth Rates (Least Squares):			
1965-77	10.3%	12.4%	1.9%
1970-77	7.8	12.4	4.4

Source: Commerce Department, Merrill Lynch estimates.

TPD of textile fiberglass. Each of these plants is planned to increase production in the FRP sector of the industry where capacity is projected to grow by about 85% between 1976 and 1982, (from 325,000 tons to 600,000 tons).[35]

Projected growth in this industry appears to indicate that some new sources will be required to meet consumer demand. While no new additional facilities have been announced, discussions within the industry indicate that both new and expanded facilities will be utilized to facilitate increased production.

This study assumes that all additional capacity required by the industry will be provided by new facilities. Industry representatives indicate that a typical new facility will produce 100 TPD of textile fiberglass. It is estimated that the equivalent of 5 new facilities will be required, in addition to the two plants presently under construction, to meet projected demand for the industry through 1982.

8.1.6 PRESSED AND BLOWN GLASS

8.1.6.1 Industry Structure

The primary descriptor of this segment of the industry is that each plant manufactures glass and glassware that is pressed, blown, or shaped from glass produced within the plant. Plants in this segment of the industry may produce consumer and/or commercial glassware. Consumer glassware includes products such as tumblers, stemware, tableware, cookware, ovenware, kitchenware, and ornamental, decorative, and novelty glassware. Commercial glassware includes products for the lighting and electronics industries and various other fields, such as the scientific and technical market.

The pressed and blown glass industry may also be subdivided into two broad divisions: (1) the machine-pressed and blown sector, which is characterized by relatively large publicly held firms that often produce products largely for their own use, and (2) the hand pressed and blown sector, which is comprised mainly of privately owned small firms that produce glassware products that are generally more expensive, and are valued by the consumer for their quality and craftsmanship.

It has been estimated that 50 firms in the industry produce approximately 98% of all pressed and blown glass shipments.[36] Corning Glass has production facilities operating in all areas of this segment, and Owens-Illinois, in most of them. More than half of the plants in the industry produce hand pressed and blown glass exclusively. Approximately 10% of the plants identified produce both hand-pressed and machine-pressed and blown products.

8.1.6.2 CONSUMER GLASSWARE

8.1.6.2.1 Machine-Pressed and Blown

8.1.6.2.1.1 Geographic Location

Seven major firms were identified as producers of machine-pressed and blown consumerware in 13 plants in 7 states of the United States. Four plants are located in the Central part of the country, one on the West Coast, and eight in the Eastern sector. There are fourteen plants that are primarily in the hand-pressed and blown sector but which have been identified as having machine-pressed and blown capabilities.

8.1.6.2.1.2 Integration and Concentration

Each of the major firms in this sector of the industry manufactures integrated multi-product lines. The sector is highly concentrated with 7 firms predominating: Corning Glass, Owens-Illinois, Anchor Hocking, Brockway, Federal Glass, Bartlett-Collins, and Jeanette Corp. Corning produces the largest-selling line of moderately priced dinnerware in the United States. In 1977, 27% of the firm's net sales were in consumerware. Owens-Illinois, through its Libbey Glass Division, is the leader in the introduction of new products -- nearly 300 during 1977. Anchor Hocking leads this sector of the industry in total glassware production. In 1977, 24% of Anchor Hocking's net sales were in glass tableware. Sales volume for each of the remaining firms identified is only about 10% of that of any of the three largest firms.[37]

8.1.6.2.1.3 Import/Export Considerations

The consumerware sector is heavily impacted by imports from a wide variety of foreign countries. Table and kitchenware represent the largest category of import in the pressed and blown segment of the glass industry. Two of the multi-national companies, Corning and Owens-Illinois, have foreign subsidiaries which supply consumerware to the European market. Export volume is relatively small, therefore, from the two firms. Anchor Hocking, of the three largest firms, is a volume exporter. In 1977, Anchor Hocking experienced a record year for profitability from the export market. Much of Anchor Hocking's consumerware is transported by ship for foreign distribution. Historically, the shipping industry has been impacted by labor disputes. The export market is significantly impacted by the volatility of the shipping industry.

8.1.6.2.1.4 Demand Determinants

In this sector, consumer taste and relative price between similar items are the major determinants of demand. Corning Glass and Anchor Hocking produce large lines of similar heat-resistant table and kitchenware. Owens-Illinois and Anchor Hocking produce similar tumbler and stemware items. Brand loyalty plays a large part in which firm's products are chosen by the consumer.

The availability of a wide variety of substitutes from the import market, especially in the tableware, tumbler, and stemware categories, provides a highly competitive structure in this sector. The impact of plastics and paper tableware products cannot be assessed.

Consumer spending for these products is small in relation to personal disposable income. Therefore, consumers are highly sensitive to variations in pricing for similar products. Demand appears to be highly price-elastic.

8.1.6.2.2 Hand-Pressed and Blown Glassware

8.1.6.2.2.1 Geographic Location

There are 84 firms that have been identified as producing hand-pressed and blown products in 90 plants in 17 states. The greatest concentration of plants is located in the Ohio-Pennsylvania-West Virginia area where 53 of the participating plants are located. West Virginia has 28 firms producing in 30 plants.

8.1.6.2.2.2 Integration and Concentration

Many of the firms participating in this sector are small and privately owned, producing in one plant only. Firms are integrated in most lines of production, such as tableware, tumblers, and stemware. However, many firms produce hand-made illuminating glassware, such as lamp globes and bases, which are sent to original equipment manufacturers for final assembly and marketing. A small number of firms also produce machine-pressed and blown items. Most hand-pressed and blown products are sold through manufacturers' representatives. Finished stemware is packaged and sold from the factory.

There is little apparent concentration in this sector of the industry. Manufacturers own their own molds and select their own designs or patterns. In the past, customers placed special orders, and products were made to order. The more recent trend is toward annual contract production. The sector is characterized by entrepreneuership.

8.1.6.2.2.3 Import/Export Considerations

The major impact on this sector of the industry comes from imported products. With import prices increasing because of devaluation of the dollar, domestically produced items are now selling on the U.S. market at prices equal to or slightly lower than imported counterparts. Mexican products are sold in California at rates lower than in other parts of the country because freight rates are low. As trade with Eastern Europe expands, however, greater quantities of hand-blown stemware and crystal may be imported.

A small percentage of hand-pressed and blown products is exported to Canada. Exports will continue to be small because of high freight costs and their impact on costs of production in an industry where labor costs have already accounted for 50% of the selling price.

8.1.6.2.2.4 Demand Determinants

Hand-pressed and blown glassware supplies that portion of the market that demands uniqueness and craftsmanship. Because large capital investment in machines and in multiple molds is not justified in this sector, the volume of production and the variety of items produced are low. Products are valued by the consumer because they are in relatively short supply and because the image of quality individual craftsmanship is attached to them.

Machine-pressed and blown products are not perfect substitutes for hand-processed items; they are high-volume, generally less expensive items, produced under quality control conditions, without individual attention to every item. Imported hand-processed items provide the most viable substitute. Plastics have made some impact on the novelty glass portion of the market. To the extent that uniqueness and the value of craftsmanship determine demand for hand-processed products, plastics are not perfect substitutes.

Hand-pressed and blown products represent luxury spending from personal disposable income. They may represent major expenditures. In periods of economic uncertainty, consumers may defer purchases of these items or may purchase a lower-cost, though imperfect, substitute. Demand appears to be highly price-elastic.

8.1.6.3 COMMERCIAL GLASSWARE

8.1.6.3.1 Lighting and Electronics

This sector of the industry includes automotive lighting glassware; search light and other lenses; electronic tube blanks; tubing and cone for electric light bulbs, flourescent and neon lights; bowls and enclosing globes, lamp chimneys, lamp parts, and shades.

8.1.6.3.2 Glass Tubing: Lighting and Electronic

8.1.6.3.2.1 Geographic Location

In this category, 4 firms were identified as manufacturing tubing in 16 plants located in 10 states. One plant is located in the Central Area of the United States, and the remaining 15 plants in the Eastern section.

8.1.6.3.2.2 Integration and Concentration

Four firms are identified with this highly concentrated category of the industry: Corning Glass, General Electric, GTE Sylvania, and Westinghouse. These firms produce multi-product lines and are integrated in areas other than glass production, as well.

Investment capital requirements for equipment in this category is so large, as is volume demanded, that small flourescent and neon light manufacturers find it more economically feasible to buy from a large firm than to produce glass tubing themselves. The major producers are large multi-product firms, and light tubing manufacture does not account for a significant portion of their sales volume.

8.1.6.3.2.3 Import/Export Considerations

Because glass tubing for lighting is such a high-volume-of-production category, import impact is minimal. A high percentage of tubing for lighting is used captively by the firms that produce it, and is sufficient for their own use. Neither imports nor exports appear to significantly influence the domestic market for lighting tubing.

Tubing for electronic tube blanks is influenced to some degree by imported, assembled, end-product capacitors, resistors, and other forms of electronic glassware components.

8.1.6.3.2.4 Demand Determinants

Tubing for the lighting industry is the high-volume, low-priced category in this sector. Flourescent and neon tubing are the lighting end-products. Demand for the product is largely from the non-residential lighting market, and is determined by the infinite need for the product. Nothing substitutes for glass in lighting, and as a result demand would appear to be relatively price-inelastic.

Electronic tubing accounts for the smallest portion of the glass tubing sector. Demand for the product is specialized and determined by the precision manufacturing needs of companies that purchase it for their own applications. This category is a very-small-volume, high-selling-price area of production. As a result, price appears to be price-sensitive.

8.1.6.3.3 Incandescent Light Bulb Blanks

8.1.6.3.3.1 Geographic Location

Two firms produce incandescent light bulb blanks in 7 plants located in five states. All plants are located in the Eastern region of the United States.

8.1.6.3.3.2 Import/Export Considerations

Because of the high volume of production in this industry domestically, neither imports nor exports significantly influence the domestic market.

8.1.6.3.3.3 Integration and Concentration

Corning Glass and General Electric produce virtually all of the incandescent light bulb blanks manufactured in the United States for both residential and non-residential use. Both firms are large, integrated, multi-product, multi-national companies.

As it is in other areas of lighting manufacture, capital investment requirements for entry into this market are huge. These light bulb blanks are produced on the Corning ribbon machine, the cost of which is estimated at $25 million. The very large inventory of finished goods that must be maintained further limits available capital. The characteristics of this category suggest a highly oligopolistic industry in which few firms participate and the capital requirements are so vast so as to preclude the entry of small firms.

8.1.6.3.3.4 Demand Determinants

There are no viable substitutes for an incandescent bulb blank. Demand for the product is consistent with demand for electrical lighting as a way of life.

Consumer taste plays some very small role as a demand determinant in the end product market. Preference for other forms of lighting, such as flourescent or neon tubing for residential use, influences demand. Mercury vapor and high-pressure sodium vapor lights, superior to incandescent lights in the amount of energy consumed, are new products being developed. To the extent that product substitutes are limited, demand appears to be relatively price-inelastic.

8.1.6.3.4 Television Tube Envelopes

8.1.6.3.4.1 Geographic Location

Four firms produce TV tube envelopes in six plants in Pennsylvania, Ohio, and Indiana. Two plants are located in Pennsylvania, three in Ohio, and one in Indiana.

8.1.6.3.4.2 Integration and Concentration

Corning Glass, Owens-Illinois, RCA, and Lancaster Glass are the only firms participating in this category of the industry. Lancaster Glass is a custom manufacturer of an integrated multi-product line of special purpose products. RCA is a major manufacturer of television sets and other home and industrial appliances and components. Corning and Owens-Illinois are large, fully-integrated manufacturers of glass multi-product lines and related products.

8.1.6.3.4.3 Import/Export Considerations

The market for TV sets, the end-product for TV tube envelopes, is sharply impacted by the availability of foreign imports. So much so, that in 1977 the U.S. and Japan entered into an "Orderly Marketing Agreement," which limited the import of Japanese color TV sets for a three-year period. From 1975 through early 1977, imports and their subsequent sales had risen dramatically. A petition was filed by Corning Glass in behalf of all of the domestic firms in the industry and eleven trade unions, before the International Trade Commission. This resulted in the "Orderly Trade Agreement." Corning, through its participation in COMPACT, the Committee to Preserve American Color Television, monitors the Agreement for the industry.

8.1.6.3.4.4 Demand Determinants

Demand for TV tube envelopes is derived from demand for TV sets. Television sets are a luxury item representing a large expenditure from personal disposable income. The state of the general economy is an indicator of how demand for a luxury item will rise or fall, depending on whether consumers defer purchases until a more economically auspicious time.

While there are available substitutes for domestically produced TV sets, there are no available substitutes for TV tube envelopes. To the extent that this TV component represents a minor portion of final product value and is without a substitute product, price elasticity of demand is considered relatively inelastic.

8.1.6.4 SCIENTIFIC AND TECHNICAL GLASSWARE

This sector of the industry includes industrial and technical glassware, laboratory glassware, pharmaceutical glass products, ophthalmic lens blanks, and optical glass tubes, rods, and cones. All of these products are considered here in two sections: Glass Tubing: Scientific and Technical; and Optical Glass.

8.1.6.4.1 Glass Tubing: Scientific and Technical

8.1.6.4.1.1 Geographic Location

Tubing for medical and pharmaceutical is produced by 4 major firms in ten plants* located in seven states. With the exception of one plant located in Illinois, all of the plants are located in the Eastern section of the U.S.

8.1.6.4.1.2 Integration and Concentration

The degree of concentration is apparent in the small number of firms participating: Owens-Illinois, Corning Glass, Schott Optical Glass, and Wheaton Glass. Owens-Illinois and Corning, the two largest participating firms, produce a fully integrated multi-product line of glass tubing and rod and tubing products. High demand items such as ampules, vials, and syringe cartridges are included as are components for highly sophisticated biomedical instruments. Producers in the industry sell to distributors, to small plants and to one another for the production of precision glass products, ophthalmic lenses, and small specialty job orders.

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*A number of these plants produce multi-product lines.

8.1.6.4.1.3 Import/Export Considerations

Tubing and rod and tubing are imported into the U.S. The extent to which they penetrate the market for medical-pharmaceutical products cannot be estimated from available public data.

Owens-Illinois and Corning have international subsidiaries in four European countries which supply the European market. Exports primarily give additional supply to foreign subsidiaries or open new markets for foreign affiliate sales.

8.1.6.4.1.4 Demand Determinants

Demand in this category is influenced by the specialized nature of the products being manufactured. Growth and advances in technology in the medical and health-related industries will influence demand. Viable substitutes for some products in this area include plastics and ceramic glass. In that both Owens-Illinois and Corning Glass maintain full production capabilities in both of these areas, substitutability of other goods is not anticipated to influence demand in this market.

This category of the glass tubing sector represents the highest volume of production in the sector. Products are medium-to-high-priced, and viable substitutes produced by the same firm create a demand which appears to be relatively price-inelastic.

8.1.6.4.2 Optical Glass

8.1.6.4.2.1 Geographic Location

Five firms in this category produce optical glass products in 8 plants located in New York, Massachusetts, Virginia, and Pennsylvania.

8.1.6.4.2.2 Integration and Concentration

The presence of only five major firms in the industry indicates a high degree of concentration. Corning Glass, American Optical, Bausch and Lomb, Eastman Kodak, and Schott Optical Glass predominate in the industry. Each of the firms is integrated in multi-product-line manufacturing.

8.1.6.4.2.3 Import/Export Considerations

The major firms in this sector of the industry are also engaged in end-product manufacture of a wide range of analytical, technical, electronic, and health-related diagnostic instruments. The sector is highly specialized, with products being produced largely by contract arrangement or to fill intra-company needs. To that extent, small inventories exist and no real impact is experienced from imported end-products.

No significant export market exists for the glass itself, except to add supply to an existing foreign subsidiary. End-product export reflects the specialized contract nature of this category and is relatively insignificant.

8.1.6.4.2.4 Demand Determinants

Optical glass and instruments are a highly specialized, high-priced, low-volume category. Demand is influenced by any growth of the electronic market, and by an expansion in government scientific and research programs. Optical glass for use in analytical instruments experiences increased demand when environmental, industrial, and aerospace programs are initiated or expanded. Any advance in biomedical research techniques brings about increased demand in this category.

Plastics have become viable substitutes in some areas of ophthalmic and instrument lens production. Plastics are, however, more expensive than glass in a sector where prices are high for glass products. In uses where weight is a factor, plastics have become a viable substitute.

The highly specialized, high-priced, low-volume nature of this category of the industry appears to indicate that price elasticity of demand is relatively inelastic.

8.1.6.7 Supply Considerations

Public reporting of shipments for the plants in the Pressed and Blown segment was available only in terms of dollar amounts, and not by volume of shipments. Neither existing capacity nor capacity utilization rate could be estimated. Because of the lack of specificity and disaggregation of the data, another methodology employing different assumptions was used to determine the number of new grassroots plants needed to meet industry growth for the next five years.

Future growth in the Pressed and Blown segment of the industry appears closely allied with general growth in the economy.[38] Items produced in the consumerware sector and much of what is produced in the hand-Pressed and Blown category represent luxury purchases or purchases that may be deferred depending on the state of the economy. Also, recent drop-offs in sales of domestically produced TV sets, because of import penetration into the market, resulted in severe curtailment in the TV envelope category of the industry. For these reasons, this section of the study assumes that the pressed and blown industry will grow at the same rate as GNP. GNP is projected to grow at an annual growth rate of 4% for the next 5 years.[39]

The number of plants in each category of the industry were estimated, and the GNP growth rate applied for 1978-1982. Projections were adjusted to accommodate the typical size of the new plant identified in each category. The results are shown in Table 8-5. Industry sources indicate that during the 1960's, major retrofit took place in plants in this segment of the industry, and that additional capacity created by those expansions has continued to be underutilized. New sources have not been announced and it is assumed that projected production demands may be met by existing sources. In order to present a worst-case scenario, however, this study assumes that all projected demand will be met by new sources.

One new plant each will be required in machine pressed and blown consumerware, incandescent bulb blanks, and TV tube envelopes. Two each are required in glass tubing, optical glass and hand-pressed and blown consumerware. It is estimated that this number of new facilities will be adequate to meet projected demand through 1982.

Table 8-5

ESTIMATED NEW SOURCES FOR PRESSED AND BLOWN GLASS

(1977-1982)

Industry	Number of Existing Plants	Production Capability of Average Plant (TPD)	Capability of New Source (TPD)	Number of Sources Required
Machine Consumerware	13	100	300	1
Hand-Pressed and Blown Consumerware	90	5	50	2
TV Envelope Tubes	6	250	400	1
Incandescent Bulb Blanks	7	175	400	1
Optical Glass	8	50	50	2
Tubing	22	100	200	2

* Estimates are based on the assumption that this segment of the industry will experience real growth of 4% from 1977 to 1982.

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8.2 COST ANALYSIS OF ALTERNATIVE CONTROL SYSTEMS

8.2.1 Introduction

Installed capital costs and annualized costs for the control of particulate emissions from new glass furnaces have been estimated for 27 combinations of model plant size, control option, and industry segment. The 27 combinations are listed in Table 8-1.

Typical parameters for uncontrolled exhaust from the selected model plants for each industry segment are given in Table 8-2. These parameters were estimated by the U.S. Environmental Protection Agency (U.S. EPA) with data obtained from plant representatives, design calculations, and various reports of source tests.

The regulatory options for particulate emissions and the emission limitation from the New Jersey State Implementation Plan (SIP), which is used as a reference to represent current requirements, as a baseline case, are shown in Table 8-3. The baseline process weight regulation for glass furnaces is shown in Figure 8-1. With the exception of the 50-tons/day model plants in the Pressed and Blown: soda-lime segment, controls would be required in order for the model plants to comply with the process weight regulation for glass furnaces in the baseline case even without a new emission limitation. The regulatory options do not entail any monitoring costs.

8.2.2 Capital Cost Estimates

Two major categories of costs have been developed: installed capital costs and total annualized costs. The installed

TABLE 8-6. CONTROL COMBINATIONS

Industry segment	Model plant size, tons/day	Regulatory option		Control device
		I	II	
Container	250	0.2	0.4	ESP
		0.2	0.4	Fabric filter
			0.4	Scrubber
Flat	700	0.3	0.6	ESP
Pressed and Blown and (borosilicate, opal, and lead)	100	0.5	1.0	ESP
	50	0.5	1.0	ESP
	100	0.5	1.0	Fabric filter
	50	0.5	1.0	Fabric filter
Pressed and Blown (soda-lime)	100	0.2	0.4	ESP
	50	0.2	0.4	ESP
	100	0.2	0.4	Fabric filter
	50	0.2	0.4	Fabric filter
Wool Fiberglass	200	0.4	0.8	ESP
	200	0.4	0.8	Fabric filter

TABLE 8-7. UNCONTROLLED EXHAUST PARAMETERS FOR MODEL PLANT[a]

Industry segment	Model plant size, tons/day	Flow rate, m^3/min	Flow rate, acfm	Temperature, °C	Temperature, °F	Emission rate, lb/ton	Total particulate loading, mg/m^3 (gr/scf)
Container	250	2266	80,000	207	405	2.5	142 (0.062)
Flat	700	8298	293,000	207	405	3.0	130 (0.057)
Pressed and blown (Borosilicate, opal, and lead)	100	2011	71,000	207	405	10.0	256 (0.112)
	50	1005	35,500	207	405	10.0	256 (0.112)
Pressed and blown (Soda-lime)	100	906	32,000	207	405	2.5	142 (0.062)
	50	453	16,000	207	405	2.5	142 (0.062)
Wool fiberglass	200	1552	54,800	207	405	10.0	664 (0.290)

[a] Based on data provided by U.S. EPA Source testing and plant visits.

TABLE 8-8. REGULATORY OPTIONS FOR PARTICULATE EMISSIONS

Industry segment	Regulatory option I, lb/ton	Regulatory option II, lb/ton	Baseline SIP requirement, lb/ton[a]
Container	0.2	0.4	0.96
Flat	0.3	0.6	0.65
Pressed and blown (borosilicate, opal, and lead)	0.5	1.0	1.70
	0.5	1.0	2.88
Pressed and blown (Soda-lime)	0.2	0.4	1.70
	0.2	0.4	2.88[b]
Wool fiberglass	0.4	0.8	1.08

[a] Values apply to model plant sizes shown in Table 8-2.

[b] The uncontrolled emission rate is 2.5 lb/ton; therefore no control is required to meet SIP.

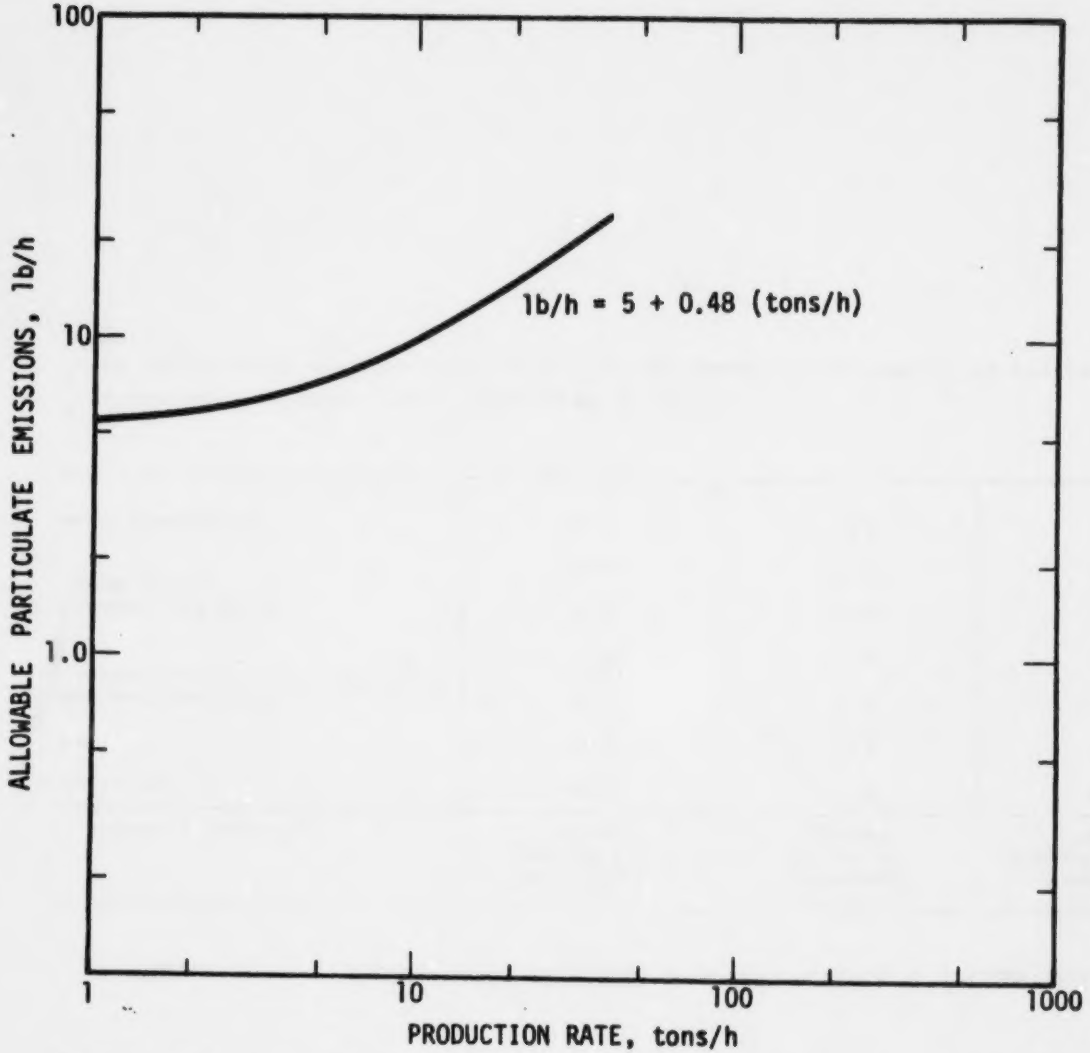

Figure 8-1. New Jersey SIP for glass manufacturing furnace, the baseline case.

capital cost of each control device includes the purchase price of the major and auxiliary equipment, the cost of site preparation, equipment installation, design engineering, the contractor's fee, and interest during construction as shown in Table 8-4. The cost of each control system is estimated by adding the installed costs of each major piece of equipment, i.e., the control device, fan, ductwork, and dampers. The cost of a stack is not included because it is considered to be part of the glass-making process and not an additional cost for particulate control. The equipment cost of fabric filters is based on the estimates in Reference 1 for custom baghouses with reverse-air or shaker cleaning. The equipment cost for the scrubber option is based on information provided by FMC Corporation.[2] The equipment cost of electrostatic precipitators (ESP's) is based on estimates relating plate area to cost for conventional plate and wire precipitators. Installation costs and indirect costs are based on published information and engineering judgment.[3-7] The total installed costs calculated in this manner for fabric filter control systems and ESP control systems are shown in Figures 8-2 and 8-3, respectively. The estimated cost for the option of installing a scrubber in the container segment is shown in Figure 8-4.

These figures also show actual control system costs as reported by industry in response to EPA inquiries (Section 114 letters). All estimated costs and reported industry costs have been indexed to January 1978 dollars using the chemical engineering cost index. The reconciliation of estimated costs and

TABLE 8-9. COMPONENT CAPITAL COSTS ESTIMATED SEPARATELY BY MODULE

Direct Cost Components[a]
Equipment
Instrumentation
Piping
Electrical
Foundation
Structural
Sitework
Insulation
Paintings
Buildings
Indirect Cost Components[a]
Field overhead
Contractor's fee
Engineering
Freight
Offsite
Taxes (5% of material)
Allowable for shakedown
Spares
Contingency (20% of total)
Interest during construction

[a] Each component cost estimated separately depending on equipment involved.

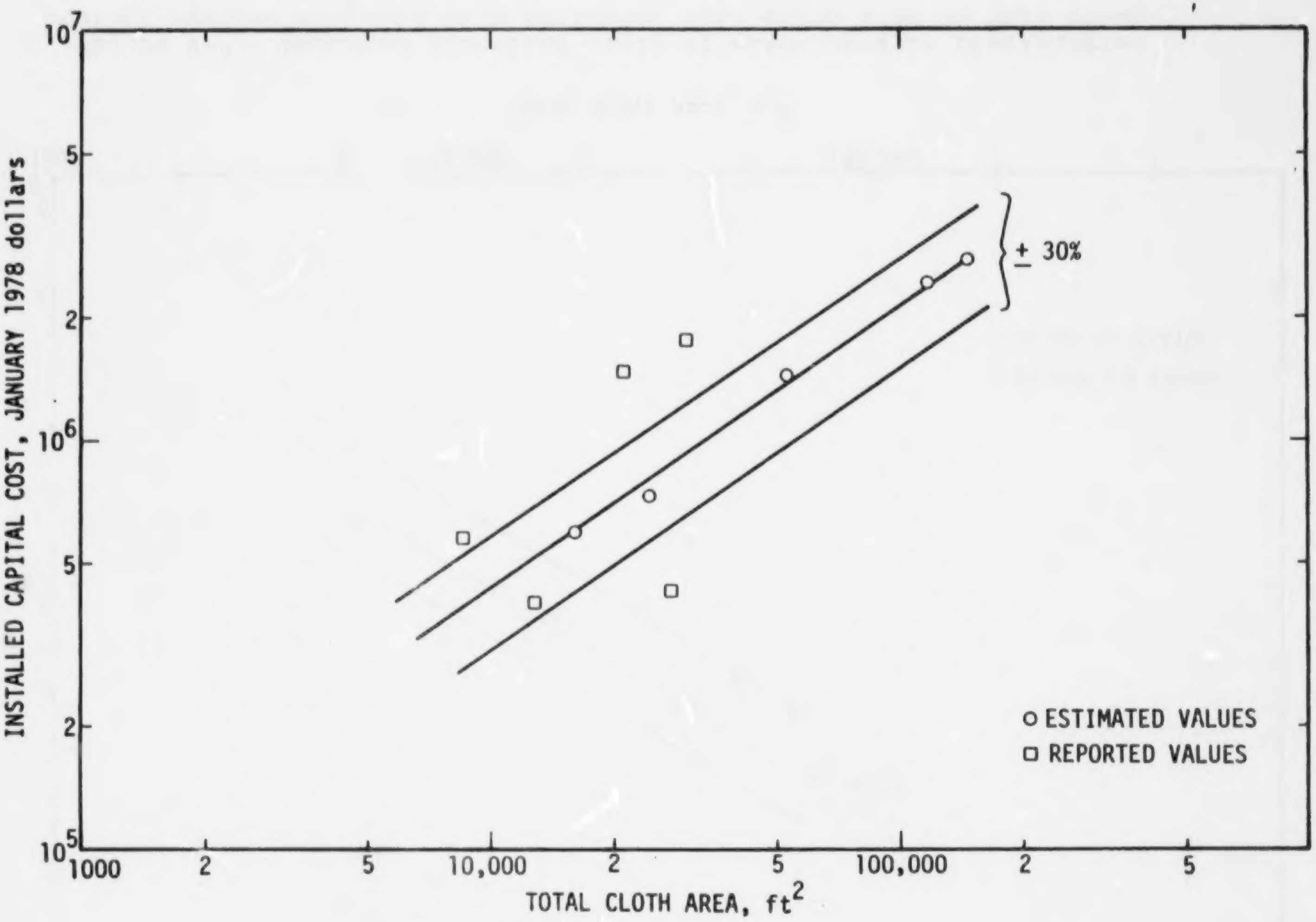

Figure 8-2. Reported installed costs of fabric filter control systems compared with estimated cost curve used in this study.

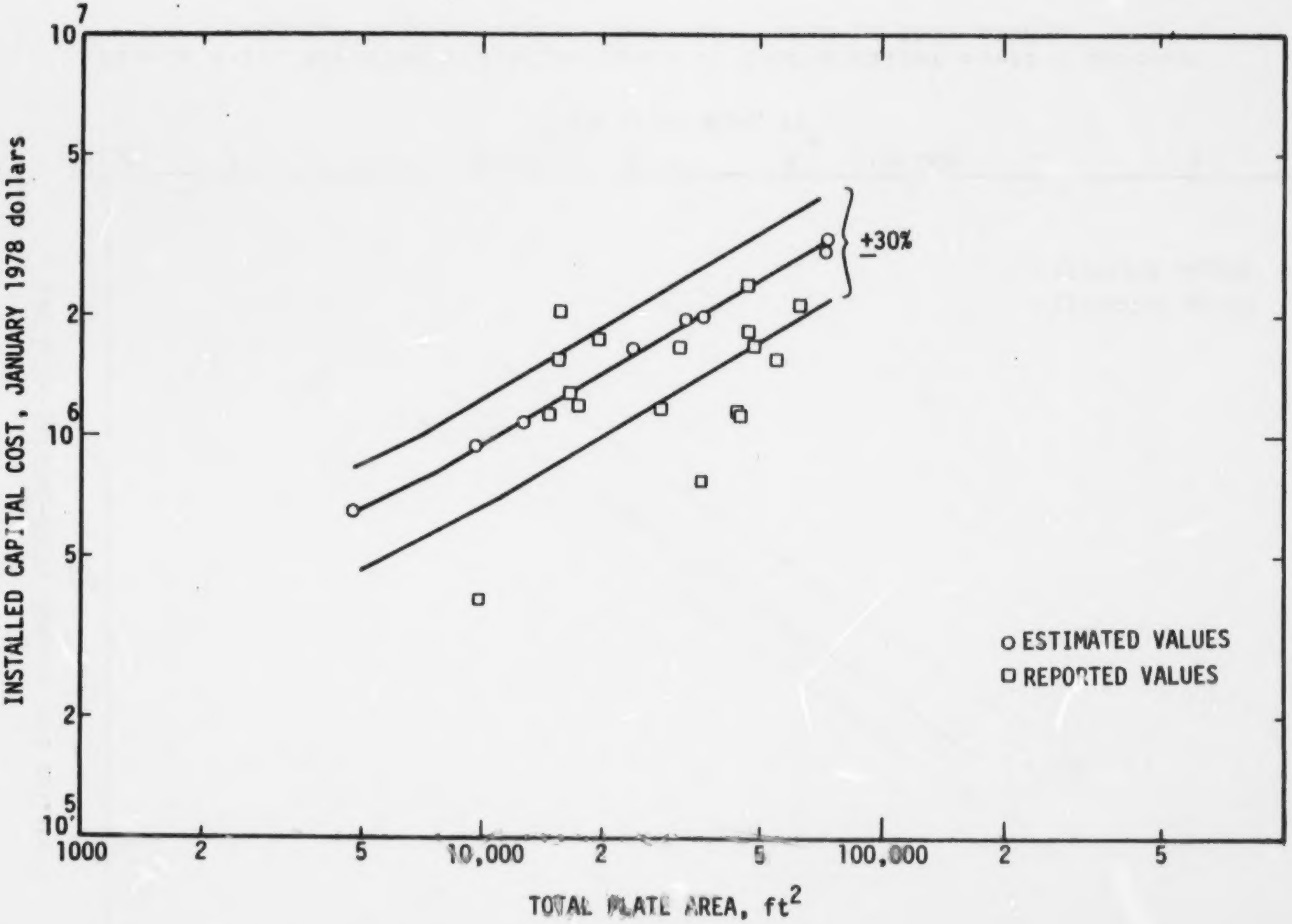

Figure 8-3. Reported installed costs of electrostatic precipitator control systems compared with estimated cost curve used in this study.

industry costs is considered to be reasonable despite the large variation in reported industry costs. Such variation is not unexpected, considering the broad range of site-specific design parameters and retrofit variations inherent in the reported industry costs.

The reported industry costs for fabric filter systems are plotted as a function of total cloth area in order to eliminate variations in air to cloth ratios and flow rates. It can be seen that the reported cost values are essentially equally scattered about the estimated cost line. The reported industry costs cover a broad range of design conditions and it is not known what auxiliary costs are included by each company. As discussed later in Section 8.5, the variation in installation costs can be significant depending upon specific plant layout and furnace configuration.

The reported industry costs for ESP systems are plotted as a function of total plate area in order to eliminate variations in specific collection area and flow rates. As in the case of fabric filters, there is overall agreement between the estimated and reported values. Several installations, however, have reported costs significantly lower than expected for the plate area reported. Discussions with plant representatives reveal several reasons for these lower costs. For example, one of the units is reported to be improperly designed and has operated for only about 2 months over a 2-year period. Another of the units is reportedly designed to achieve only 50 percent efficiency. Other reasons for the low costs in general include the ease of installation in a convenient location close to the furnace, low installation labor costs, and the inability to accurately allocate individual unit cost in multi-unit installations.

Figure 8-4 shows the reported industry costs for scrubbers compared to the one scrubber case which was estimated. Also shown are estimates for a scrubber system quoted in Reference 8 and inflated from a base reference year of 1974. No costs of water treatment are believed to be included in the reported industry costs and therefore, the water treatment costs were deleted from the estimated value which is shown. There are insufficient data to make any firm comparison of estimated and actual costs, but the location of the points suggests that there is good agreement between the reported and estimated costs.

Estimated costs in all cases are based on the use of heavy-duty equipment, liberal installation allowances, and 20 percent contingency. No attempt was made to include costs of research and development, cost of land, possible loss of production during equipment installation, or losses during startup.

It can be seen from Figure 8-3 that the relationship between cost and the size of the control system follows an increasing logarithmic relationship such that a doubling of plate area results in a cost increase of about 1.5 times. This behavior is often referred to as the "0.6 rule" because the proportional increase in cost is equal to the ratio of plate areas raised to the 0.6 power. The fabric filter curve in Figure 8-2 more closely

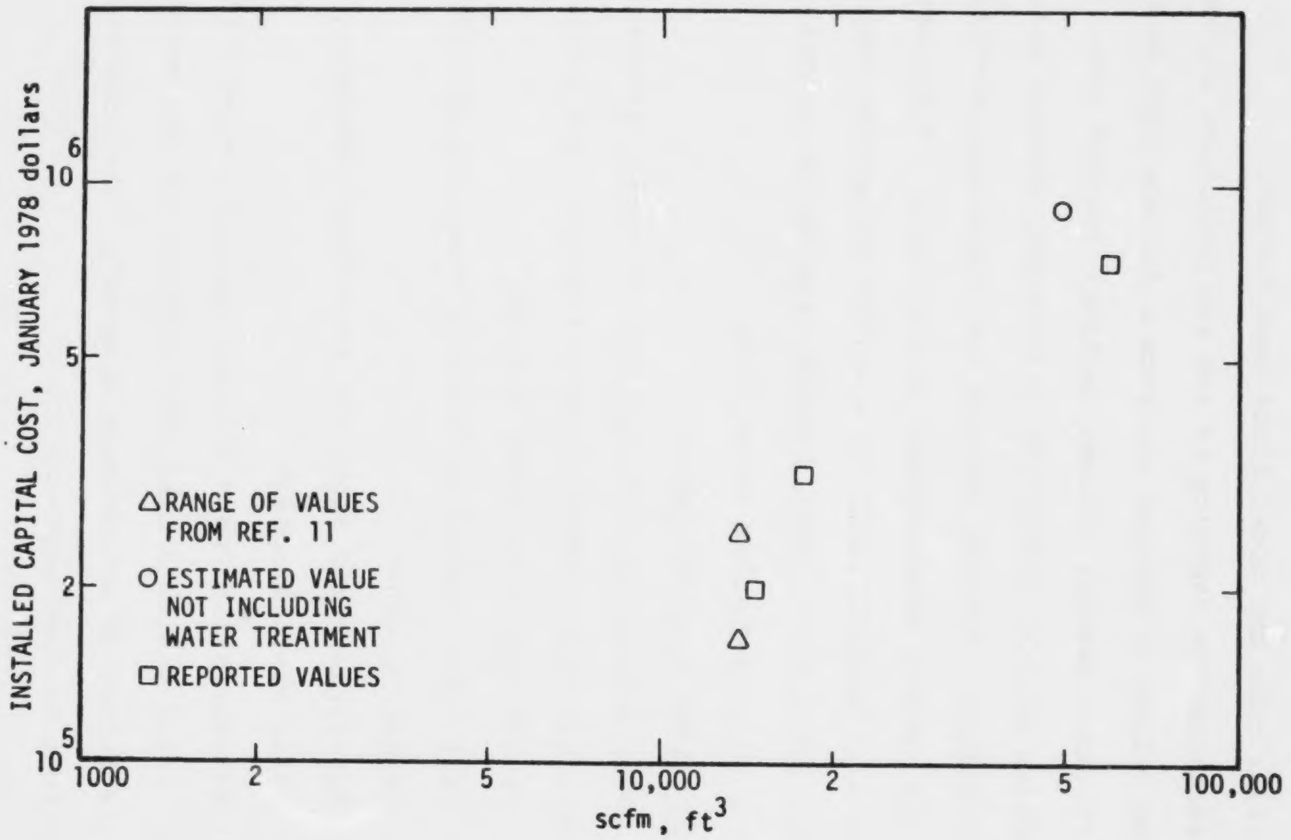

Figure 8-4. Reported installed costs of scrubber control systems compared with estimated cost curve used in this study.

follows a 0.7 power relationship. There are insufficient data to define the scrubber curve in Figure 8-4. These relationships can be used to estimate the costs of control for furnaces larger and/or smaller than the model sizes used herein.

To determine the capacity of the air pollution control system, the volume of exhaust gas from a furnace must be known. Factors affecting exhaust volumes include: furnace size; pull rate; drafting system; combustion efficiency; checker volume; and furnace condition. Exhaust volumes for comparable conditions, however, are roughly proportional to pull rate. Therefore, given a specific air-to-cloth ratio or specific collection area (SCA), the control costs for a given furnace size can be roughly estimated using the appropriate power rule.

8.2.3 Annualized Cost Estimates

The total annualized cost consists of three categories: direct operating cost, indirect operating cost, and capital charges. Direct operating costs include:

- Utilities, including electric power and process water
- Operating labor
- Maintenance and supplies, including chemicals, and
- Solid waste disposal

Indirect operating costs include payroll overhead and plant overhead. Plant visits showed that landfilling was uniformly used as the method of solid-waste disposal. The industry therefore, receives no dust recovery credit.

Water pollution control costs arise only when a scrubber is installed in the Container Glass segment. Industry response to EPA inquiries indicates that the predominant method of scrubber wastewater disposal is discharge to municipal treatment plants. A wastewater treatment system is included with the scrubber control option because pretreatment standards and effluent standards for the glass industry are expected to require treatment by 1981.

Capital charges include: depreciation; interest; property taxes; and insurance. Depreciation and interest are computed by use of a capital recovery factor (CRF), the value of which depends on the operating life of the device and the interest rate. (An operating life of 15 years and an annual interest rate of 10 percent are assumed.) Taxes and insurance costs are estimated at an additional 4.0 percent of the installed capital cost per year. The values used to calculate annualized costs are summarized in Table 8-5.

Annualized costs for the operation of control devices are a function of the number of operating shifts per day. For purposes of this study, all facilities were assumed to be in operation 95 percent of the time, thereby requiring 8320 operating hours per year. The operating labor required is based on having one man on the day shift for the dust-handling operation. For the small units, collecting less than 300 lb/day, the operating labor requirement is reduced by one-half. No operator is included for the scrubber option.

TABLE 8-10. CALCULATION OF ANNUALIZED COSTS OF AIR POLLUTION CONTROL SYSTEMS

Cost component	Method of calculation
Direct operating costs	
Utilities	
Water	Amount used per year x \$0.25/1000 gal
Electricity	Amount used per year x \$0.03/kWh[a]
Operating labor	
Direct	Number of man-hours per year x \$7.00/hour[b]
Supervision	20% of direct labor hours x \$8.40/hour[c]
Maintenance and supplies	
Labor and material	6% of total capital costs
Supplies	15% of labor and material
Solid waste disposal	Amount of collected dust x \$5.30/ton[d]
Sodium carbonate for scrubber	Amount used x \$55/ton
Indirect operating costs	
Overhead	
Plant overhead	50% of operating labor plus 50% of maintenance and supplies
Payroll overhead	20% of operating labor
Fixed costs	
Capital recovery	13.2% of total capital cost[e]
Taxes and insurance	4% of total capital costs

[a] Electrical consumption is based on the control device operating 8320 h/yr.

[b] Labor rate based on data in Reference 9 projected to January 1978 dollars. Labor required is 2920 h/yr for large units and 1460 h/yr for small units for dust handling.

[c] Based on 120% of labor rate.

[d] Based on data in Reference 10.

[e] For all air pollution control equipment, 15 year life, 10 percent interest assumed.

8.2.4 Description of Control Systems

The control systems for which costs have been estimated are fabric filters, ESP's, and a combination packed-bed/venturi scrubber system, all of which are technically capable of achieving the various emission reductions. Each system includes all appropriate auxiliary equipment such as: fans; motors; drives; pumps; ductwork; dampers; walkways; and ladders. In general, equipment selection is based on heavy-industry specifications. Ductwork is 1/4-in. carbon steel with allowance for expansion joints and access doors. Fans have radial tip blades with totally enclosed motors. Motor size is based on cold startup. Dampers are included for emergency bypassing.

Fabric filter costs are based on the air-to-cloth ratios shown in Table 8-6. The fabric filters are insulated to maintain the operating temperature at 405°F and prevent condensation in the baghouse. Glass bags are used at this elevated temperature. No cooling or other preconditioning of the furnace exhaust gases is included.

Electrostatic precipitator costs are based on a conventional plate and wire design. The ESP's are insulated and covered. The required collection area is based upon the data given in Table 8-6. No cooling or preconditioning of the furnace exhaust gas is included. The larger ESP's and fabric filters are equipped with dust-handling conveyors and storage bins, even though the total dust collected is less than 1 ton/day. The relatively large size of the units requires more than one hopper and consequently a

TABLE 8-11. CONTROL DEVICE PARAMETERS FOR REGULATORY OPTIONS AND BASELINE SIP

Industry segment	Model plant size, tons/day	Regulatory option, lb/ton	Collection area required-ESP, ft^2/1000 acfm[a]	Air/Cloth ratio required baghouse[a]	Pressure drop required scrubber, in. H_2O[a]
Container	250	0.2	400	0.65:1	
		0.4	300	0.65:1[e]	30[b]
		0.96 (SIP)	156[c]	NA[d]	20
Flat	700	0.3	330	NA	
		0.6	250	NA	
		0.65 (SIP)	227[c]	NA	
Pressed and blown (borosilicate, opal, and lead))	100	0.5	1000	0.6:1	
		1.0	600	0.6:1[e]	
		1.7 (SIP)	526[c]	NA[d]	
	50	0.5	1000	0.6:1	
		1.0	600	0.6:1[e]	
		2.88 (SIP)	368[c]	NA[d]	
Pressed and blown (soda-lime)	100	0.2	400	0.65:1	
		0.4	300	0.65:1[e]	
		1.7 (SIP)	65[c]	NA[d]	
	50	0.2	400	0.65:1	
		0.4	300	0.65:1[e]	
		2.88 (SIP)	0	0	
Wool fiberglass	200	0.4	1100	0.85:1	
		0.8	800	0.85:1[e]	
		1.08 (SIP)	723[c]	0.85:1[e]	

[a] The collection areas, air to cloth ratios, and pressure drop required to meet the regulatory options are based on data provided by the Emissions Standards and Engineering Division, OAQPS, U.S. EPA.

[b] Scrubber applicable only in container segment.

[c] Calculated from Deutsch-Anderson equation using an average migration velocity derived from the specific plate areas required for the regulatory options.

[d] The SIP control device is an ESP based upon the lower cost relative to a fabric filter.

[e] Costs are based on a total cloth area reflecting the portion of the gas stream requiring treatment.

NA - Not applicable.

conveyor system. For the small units with one hopper, only a dumpster box is provided. Cost of containers such as bags or drums for transport of the collected dust to a disposal site is insignificant relative to the total annualized cost. No dust agglomeration or other processing of the collected dust is considered.

A scrubber system is used only in the Container Glass segment of the industry. Costs for the scrubber installation are based on the system illustrated in Section 4. Equipment cost is based on information provided by FMC Corporation.[2] The capital cost and annualized cost of water treatment are based on a system treating a blowdown stream from the scrubber of 7200 gal/day.[11] The system consists of precipitation with lime and coagulants, clarification, filtration, and sludge thickening. Sludge from the wastewater treatment system will contain heavy metals and cannot be disposed of indiscriminately. A sludge disposal cost of $5.90/ton is included.

The estimated total costs of each control system are shown in Tables 8-7 to 8-11. Not all of the control costs are attributable to the regulatory options since all of the facilities, except four, require controls to meet the baseline SIP regulations. The costs of these SIP controls must be deducted from the total control costs to obtain the cost attributable to the regulatory options. For estimating baseline SIP control costs, it is assumed that either the same type of control device is used to meet the SIP as is used to meet the regulatory option, or an ESP is used

TABLE 8-12. CAPITAL COSTS OF PARTICULATE CONTROL FOR NEW GLASS FURNACES - CONTAINER SEGMENT

Regulatory option (OPT.)	Model plant size, tons/day	Control device	Particulate emissions, kg/day		Particulate emissions, lb/day		Effectiveness of particulate control, percent		Installed cost, Jan. 1978 dollars x 1000		Installed cost of control allocable to OPT., Jan. 1978 dollars x 1000
			SIP	OPT.	SIP	OPT.	SIP	OPT.	SIP	OPT.	
I	250	ESP	109	23	240	50	62	92	1245	1931	686
II	250	ESP	109	45	240	100	62	84	1245	1682	437
I	250	Fabric filter	109	23	240	50	62	92	1245[a]	2402[b]	1157
II	250	Fabric filter	109	45	240	100	62	84	1245[a]	2270[c]	1025
II	250	Scrubber	109	45	240	100	62	84	990	1018	28

OPT. - Regulatory option.

[a] The SIP control device is an ESP in this case. No data are available to determine if a fabric filter with a higher air/cloth ratio could be used to achieve 62% efficiency. A fabric filter system to treat a portion of the gas stream corresponding to 62% efficiency is estimated to cost $1,974,000. Therefore, an ESP represents the lowest SIP cost.

[b] No data are available to determine that a lower air/cloth ratio is required to meet 92% efficiency compared with 84%. The air/cloth ratio specified for 84% efficiency is 0.65:1. It is assumed that such a fabric filter would be equally capable of achieving 92% efficiency.

[c] Cost estimate is based on a fabric filter with 0.65:1 air-to-cloth ratio operating at 92% efficiency and treating only a portion of the gas stream to achieve an overall efficiency of 84%.

TABLE 8-13. CAPITAL COSTS OF PARTICULATE CONTROL FOR NEW GLASS FURNACES - FLAT SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Particulate emissions, kg/day		Particulate emissions, lb/day		Effectiveness of particulate control, percent		Installed cost, Jan. 1978 dollars x 1000		Installed cost of control allocable to OPT., Jan. 1978 dollars x 1000
			SIP	OPT.	SIP	OPT.	SIP	OPT.	SIP	OPT.	
I	700	ESP	207	95	455	210	78	90	2973	3578	605
II	700	ESP	207	191	455	420	78	80	2973	3116	143

OPT. - Regulatory option.

TABLE 8-14. CAPITAL COSTS OF PARTICULATE CONTROL FOR NEW GLASS FURNACES - PRESSED AND BLOWN (BOROSILICATE, OPAL, AND LEAD) SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Particulate emissions				Effectiveness of particulate control, percent		Installed cost, Jan. 1978 dollars x 1000		Installed cost of control allocable to OPT., Jan. 1978 dollars x 1000
			kg/day		lb/day						
			SIP	OPT.	SIP	OPT.	SIP	OPT.	SIP	OPT.	
I	100	ESP	76	23	168	50	83	95	2084	2881	797
II	100	ESP	76	45	168	100	83	90	2084	2225	141
I	100	Fabric filter	76	23	168	50	83	95	2084	2347	263
II	100	Fabric filter	76	45	168	100	83	90	2084	2266	182
I	50	ESP	65	11	144	25	71	95	1215	1974	759
II	50	ESP	65	23	144	50	71	90	1215	1535	320
I	50	Fabric filter	65	11	144	25	71	95	1215[c]	1450	235
II	50	Fabric filter	65	23	144	50	71	90	1215[c]	1401[b]	186

OPT. - Regulatory option.

[a] The SIP control device is an ESP in this case. No data are available to determine if a fabric filter with a higher air/cloth ratio could be used to achieve 83% efficiency. The cost estimate for a fabric filter system to treat only a portion of the gas stream corresponding to 83% efficiency is $2,151,000. Therefore an ESP represents the lowest SIP cost.

[b] Based on treating a portion of the gas stream corresponding to 90% efficiency.

[c] The SIP control device is an ESP in this case. No data are available to determine if a fabric filter with a higher air/cloth ratio could be used to achieve 71% efficiency. The cost estimate for a fabric filter system to treat a portion of the gas stream corresponding to 71% efficiency is also $1,215,000, but operating costs are higher.

TABLE 8-15. CAPITAL COSTS OF PARTICULATE CONTROL FOR NEW GLASS FURNACES - PRESSED AND BLOWN (SODA-LIME) SEGMENT

Regulatory option (OPT.)	Model plant size, tons/day	Control device	Particulate emissions, kg/day		Particulate emissions, lb/day		Effectiveness of particulate control, percent		Installed cost, Jan. 1978 dollars x 1000		Installed cost of control allocable to OPT., Jan. 1978 dollars x 1000
			SIP	OPT.	SIP	OPT.	SIP	OPT.	SIP	OPT.	
I	100	ESP	76	9	168	20	33	92	487	1100	613
II	100	ESP	76	18	168	40	33	84	487	933	446
I	100	Fabric filter	76	9	168	20	33	92	487[a]	1254[b]	767
II	100	Fabric filter	76	18	168	40	33	84	487[a]	1169[c]	682
I	50	ESP	57	5	125[d]	10	0	92	0	738	738
II	50	ESP	57	9	125[d]	20	0	84	0	644	644
I	50	Fabric filter	57	5	125[d]	10	0	92	0	711[b]	711
II	50	Fabric filter	57	9	125[d]	20	0	84	0	676[c]	676

OPT. - Regulatory option.

[a] The SIP control device is an ESP in this case. No data is available to determine if a fabric filter with a higher air/cloth ratio could be used to achieve only 33% efficiency. A cyclone is not applicable. The cost estimate for a fabric filter system to treat a portion of the gas stream corresponding to 33% efficiency is $748,000. Therefore an ESP represents the lowest SIP cost.

[b] No data is available to determine that a lower air/cloth ratio is required to meet 92% efficiency compared to 84%. The air/cloth ratio specified for 84% efficiency is 0.65:1. It is assumed that such a fabric filter would be equally capable of achieving 92% efficiency.

[c] Cost estimate is based on a fabric filter system operating at 0.65:1 air to cloth ratio and 92% efficiency and treating only a portion of the gas stream to achieve an overall efficiency of 84%.

[d] SIP regulation would allow 144 pounds per day, but the uncontrolled emission rate is 125 pounds/day.

TABLE 8-16. CAPITAL COSTS OF PARTICULATE CONTROL FOR NEW GLASS FURNACES - WOOL FIBERGLASS SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Particulate emissions, kg/day		Particulate emissions, lb/day		Effectiveness of particulate control, percent		Installed cost, Jan. 1978 dollars x 1000		Installed cost of control allocable to OPT., Jan. 1978 dollars x 1000
			SIP	OPT.	SIP	OPT.	SIP	OPT.	SIP	OPT.	
I	200	ESP	98	36	216	80	89	96	2154	2658	504
I	200	Fabric filter	98	36	216	80	89	96	1536[a]	1606	70
II	200	ESP	98	73	216	160	89	92	2154	2265	111
II	200	Fabric filter	98	73	216	160	89	92	1536[a]	1567[a]	31

OPT. - Regulatory option.

[a] No data are available to conclude that a higher air/cloth ratio could be used to achieve the lower efficiency required under SIP or the less stringent regulatory option. The collecting area required by an ESP to meet the SIP efficiency results in a higher cost for an ESP system compared with a fabric filter. Therefore the SIP costs and the less stringent regulatory option cost are based on air/cloth ratio of 0.85:1 with only the required proportion of the gas stream treated.

that can be more readily sized to the lower SIP efficiency requirements. Even at the low efficiency required in some cases to meet SIP, a centrifugal collector will not be suitable because of the extremely fine particle size of glass furnace emissions.

8.2.5 Modified/Reconstructed Facilities

The cost for installing a control system in an existing plant that has been modified, reconstructed, or expanded (given the same exhaust gas parameters) is greater, as a result of special design considerations, more complex duct runs, and similar features.

Estimating this additional installation cost or retrofit penalty is difficult because of many factors peculiar to the individual plant. Configuration of equipment in the existing plant governs the location of the control system. Depending on process or stack location, long ducting runs from ground level to the control device and to the stack may be required. A sizable increase in costs may be incurred if the control equipment must be placed on the roof, which may require steel structural support. Modification of the electrical substation may be required to accomodate an increased electrical load. Other cost components that may be increased because of space restrictions and plant configurations are: contractor's fees and engineering fees. These fees, estimated at 15 percent and 10 percent, respectively, under normal conditions, can be expected to increase to 20 percent and 15 percent, respectively, for a retrofit. These fees vary from place to place and job to job depending on the difficulty of the job, the risks involved, and current economic conditions.

The requirement for additional ducting can vary considerably, depending on plant configuration. For purposes of this study, it is estimated that approximately 50 percent more ducting may be required to install a control system in an existing plant.

If the space is tight within the plant, it may be necessary to install the control equipment on the roof. It is estimated that a roof-top installation could double the structural costs. It is estimated that 10 percent is required to tie the system into the process. This work would most likely have to be done at premium-time wage rates in order to avoid extensive downtime and loss of production.

Consideration of these additional cost factors shows that the costs of a retrofit installation may be expected to run approximately 20 percent higher than the cost of a new installation.

8.2.6 Cost-effectiveness

Incremental annualized costs (that is, costs due solely to the regulatory options) are divided by the incremental quantities of particulate removed to obtain cost-effectiveness quotients. Tables 8-12 to 8-16 list these cost-effectiveness quotients for each of the 27 control combinations. The quotients for all the control alternatives are plotted by industry segment in Figures 8-5 through 8-8. It is clear that the quotients vary both with the plant capacity and the control alternative. The quotients vary from $0.39 to $6.30/lb removed, and are strongly influenced by the SIP control efficiency relative to the regulatory option control efficiency.

Table 8-17. INCREMENTAL ANNUALIZED COSTS OF PARTICULATE CONTROLS ALLOCABLE TO THE REGULATORY OPTIONS FOR A NEW GLASS FURNACE - CONTAINER SEGMENT

Regulatory option (OPT.)	Model plant size, tons/day	Control device	Effectiveness of particulate removal, units/yr[a]		Incremental direct costs, $1000/yr[b]	Incremental annualized capital,[c] $1000/yr	Incremental total annualized costs, $1000/yr	Dollars per unit removed,	
			kg	lb				kg	lb
I	250	ESP	29,800	65,900	62	142	204	6.81	3.09
II	250	ESP	22,100	48,600	39	90	129	5.85	2.66
I	250	Fabric filter	29,800	65,900	101	250	351	11.73	5.33
II	250	Fabric filter	22,100	48,600	88	218	306	13.87	6.30
II	250	Scrubber	22,100	48,600	13	6	19	0.86	0.39

[a] (SIP emissions - regulatory option emissions) x 347 days/yr.

[b] Direct operating cost of Regulatory Option control device minus direct operating cost of SIP control device.

[c] Includes indirect operating costs of plant overhead and payroll overhead.

TABLE 8-18. INCREMENTAL ANNUALIZED COSTS OF PARTICULATE CONTROLS ALLOCABLE TO THE REGULATORY OPTIONS FOR A NEW GLASS FURNACE - FLAT SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Effectiveness of particulate removal, units/yr[a]		Direct costs, $1000/yr[b]	Annualized capital, $1000/yr[c]	Incremental Total annualized costs, $1000/yr	Dollars per unit removed,	
			kg	lb				kg	lb
I	700	ESP	38,600	85,000	65	125	190	4.92	2.23
II	700	ESP	5,500	12,100	15	30	45	8.19	3.72

[a] (SIP emissions - regulatory option emissions) x 347 days/yr.

[b] Direct operating cost of Regulatory Option control device minus direct operating cost of SIP control device.

[c] Includes indirect operating costs of plant overhead and payroll overhead.

TABLE 8-19. INCREMENTAL ANNUALIZED COSTS OF PARTICULATE CONTROLS ALLOCABLE TO THE REGULATORY OPTIONS FOR A NEW GLASS FURNACE - PRESSED AND BLOWN (BOROSILICATE, OPAL, AND LEAD) SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Effectiveness of particulate removal, units/yr[a]		Incremental direct costs, $1000/yr[b]	Incremental annualized capital, $1000/yr[c]	Incremental total annualized costs, $1000/yr	Dollars per unit removed,	
			kg	lb				kg	lb
I	100	ESP	18,600	40,900	80	165	245	13.19	5.99
II	100	ESP	10,700	23,600	14	29	43	4.00	1.82
I	100	Fabric filter	18,600	40,900	19	64	83	4.47	2.03
II	100	Fabric filter	10,700	23,600	11	45	56	5.23	2.37
I	50	ESP	18,800	41,300	69	157	226	12.05	5.47
II	50	ESP	14,800	23,600	28	66	94	8.77	3.98
I	50	Fabric filter	18,800	41,300	20	53	73	3.89	1.77
II	50	Fabric filter	14,800	32,600	16	42	58	3.92	1.78

[a] (SIP emissions - regulatory option emissions) x 347 days/yr.

[b] Direct operating cost of Regulatory Option control device minus direct operating cost of SIP control device.

[c] Includes indirect operating costs of plant overhead and payroll overhead.

TABLE 8-20. INCREMENTAL ANNUALIZED COSTS OF PARTICULATE CONTROLS ALLOCABLE TO THE REGULATORY OPTIONS FOR A NEW GLASS FURNACE - PRESSED AND BLOWN (SODA-LIME) SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Effectiveness of particulate removal, units/yr[a]		Incremental direct costs, $1000/yr[b]	Incremental annualized capital, $1000/yr[c]	Incremental total annualized costs, $1000/yr	Dollars per unit removed,	
			kg	lb				kg	lb
I	100	ESP	23,300	51,400	50	127	177	7.58	3.44
II	100	ESP	20,200	44,400	37	95	132	6.55	2.97
I	100	Fabric filter	23,300	51,400	64	164	228	9.77	4.44
II	100	Fabric filter	20,200	44,400	57	148	205	10.17	4.62
I	50	ESP	18,100	39,900	70	161	231	12.75	5.79
II	50	ESP	16,500	36,400	62	142	204	12.34	5.60
I	50	Fabric filter	18,100	39,900	69	158	227	12.53	5.69
II	50	Fabric filter	16,500	36,400	66	149	215	13.01	5.91

[a] (SIP emissions - regulatory option emissions) x 347 days/yr.

[b] Direct operating cost of Regulatory Option control device minus direct operating cost of SIP control device.

[c] Includes indirect operating costs of plant overhead and payroll overhead.

TABLE 8-21. INCREMENTAL ANNUALIZED COSTS OF PARTICULATE CONTROLS ALLOCABLE TO THE REGULATORY OPTIONS FOR A NEW GLASS FURNACE - WOOL FIBERGLASS SEGMENT

Regulatory option	Model plant size, tons/day	Control device	Effectiveness of particulate removal, units/yr[a]		Incremental direct costs, $1000/yr[b]	Incremental annualized capital, $1000/yr[c]	Incremental total annualized costs, $1000/yr	Dollars per unit removed,	
			kg	lb				kg	lb
I	200	ESP	21,400	47,200	50	104	154	7.19	3.26
I	200	Fabric filter	21,400	47,200	5	14	19	0.89	0.40
II	200	ESP	8,800	19,400	11	23	34	3.86	1.75
II	200	Fabric filter	8,800	19,400	2	7	9	1.02	0.46

[a] (SIP emissions - regulatory option emissions) x 347 days/yr.

[b] Direct operating cost of Regulatory Option control device minus direct operating cost of SIP control device.

[c] Includes indirect operating costs of plant overhead and payroll overhead.

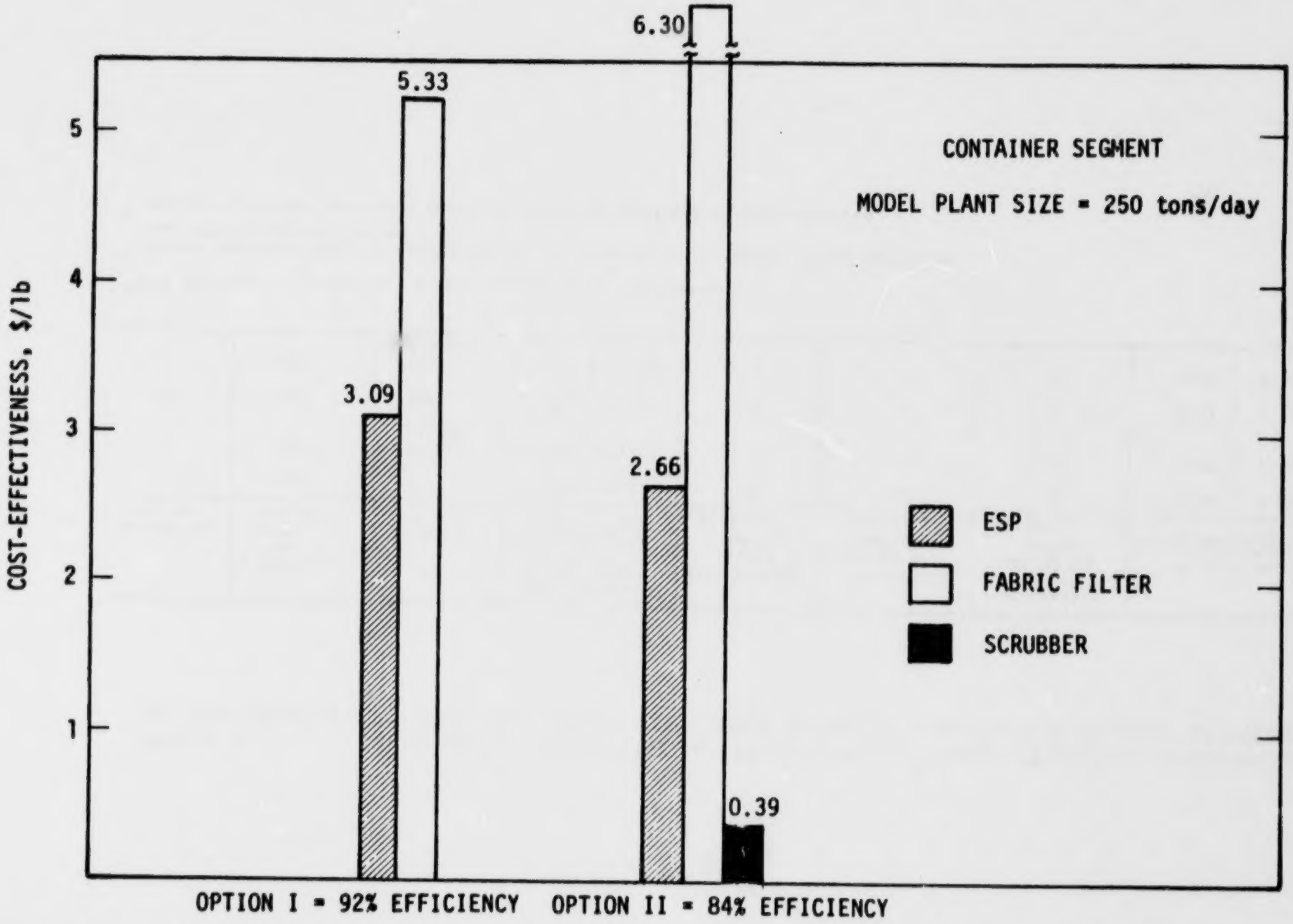

Figure 8-5. Cost-effectiveness of control options for the Container segment.

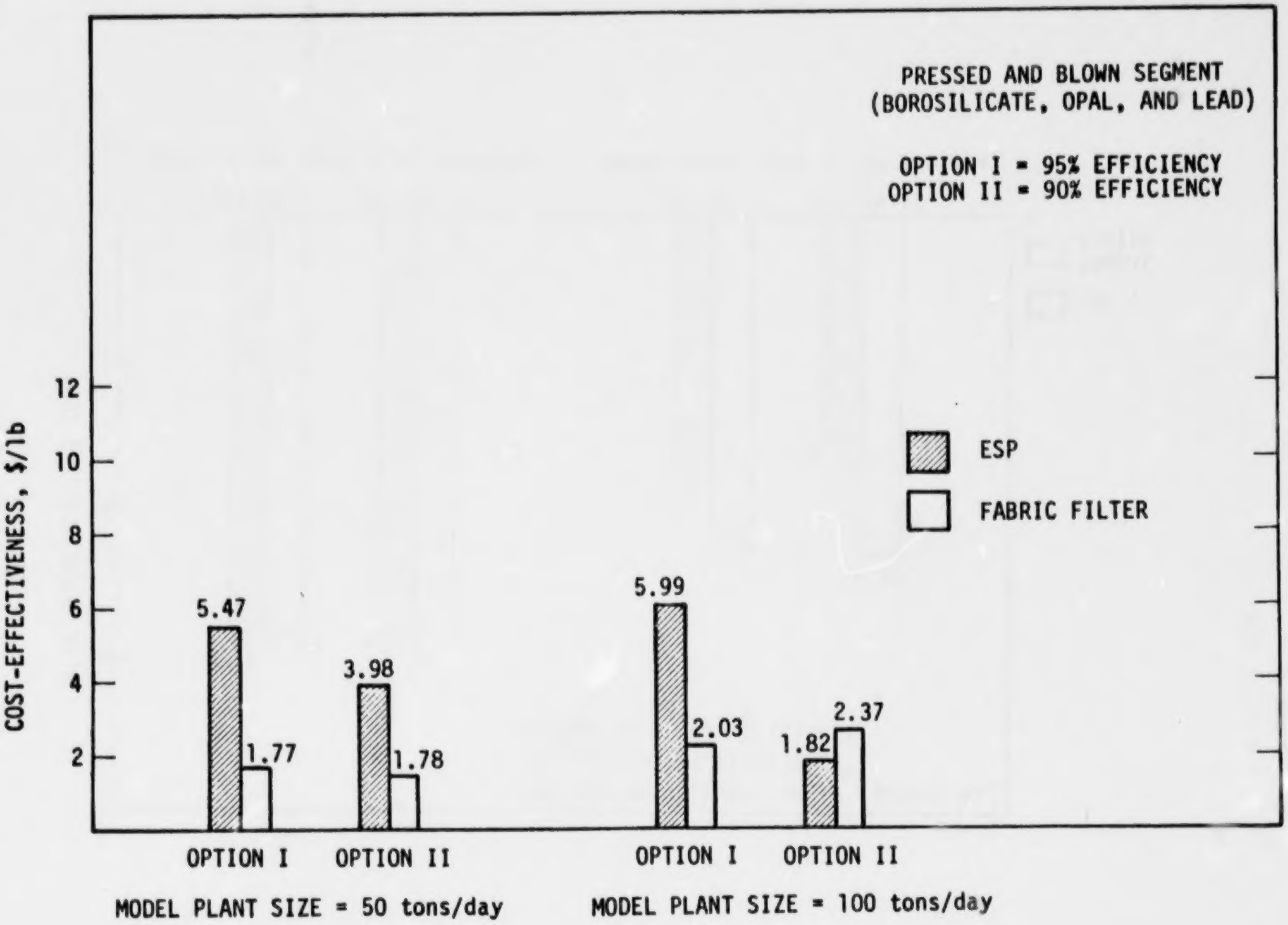

Figure 8-6. Cost-effectiveness of control options for the Pressed and Blown (borosilicate, opal, and lead) segment.

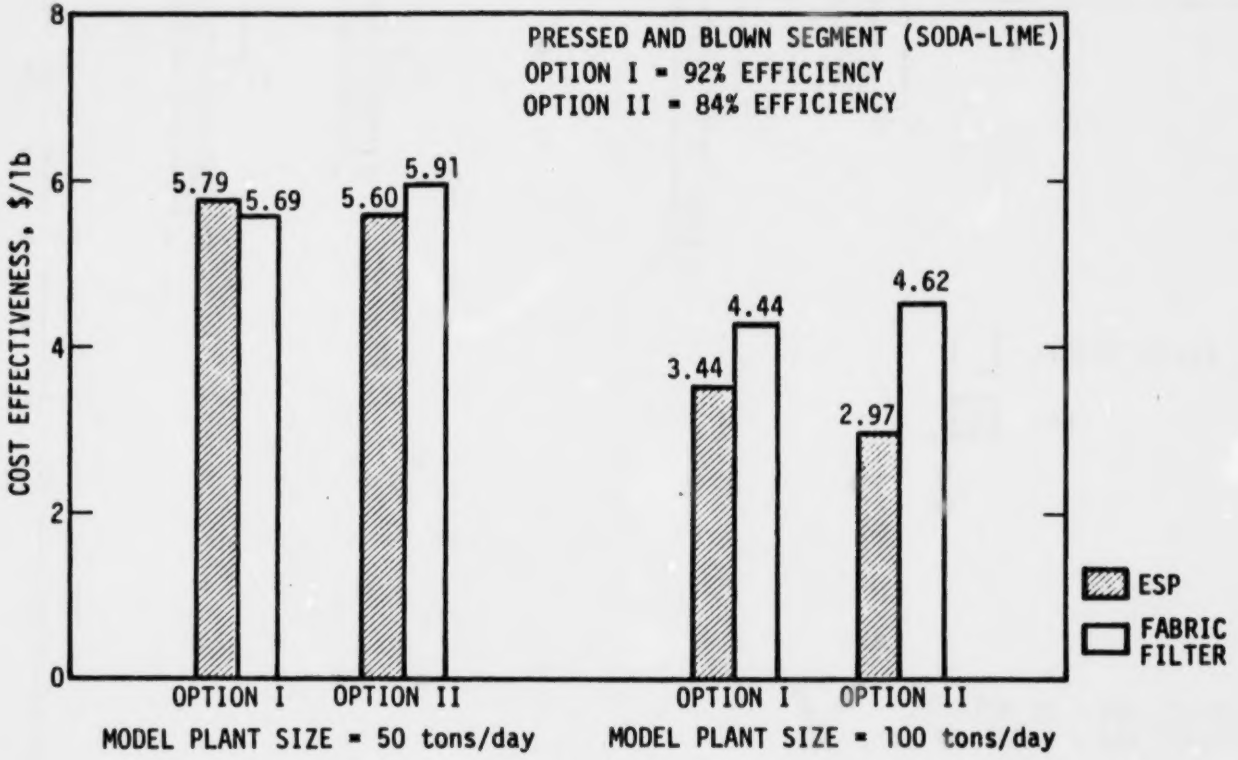

Figure 8-7. Cost-effectiveness of control options for the Pressed and Blown (soda-lime) segment.

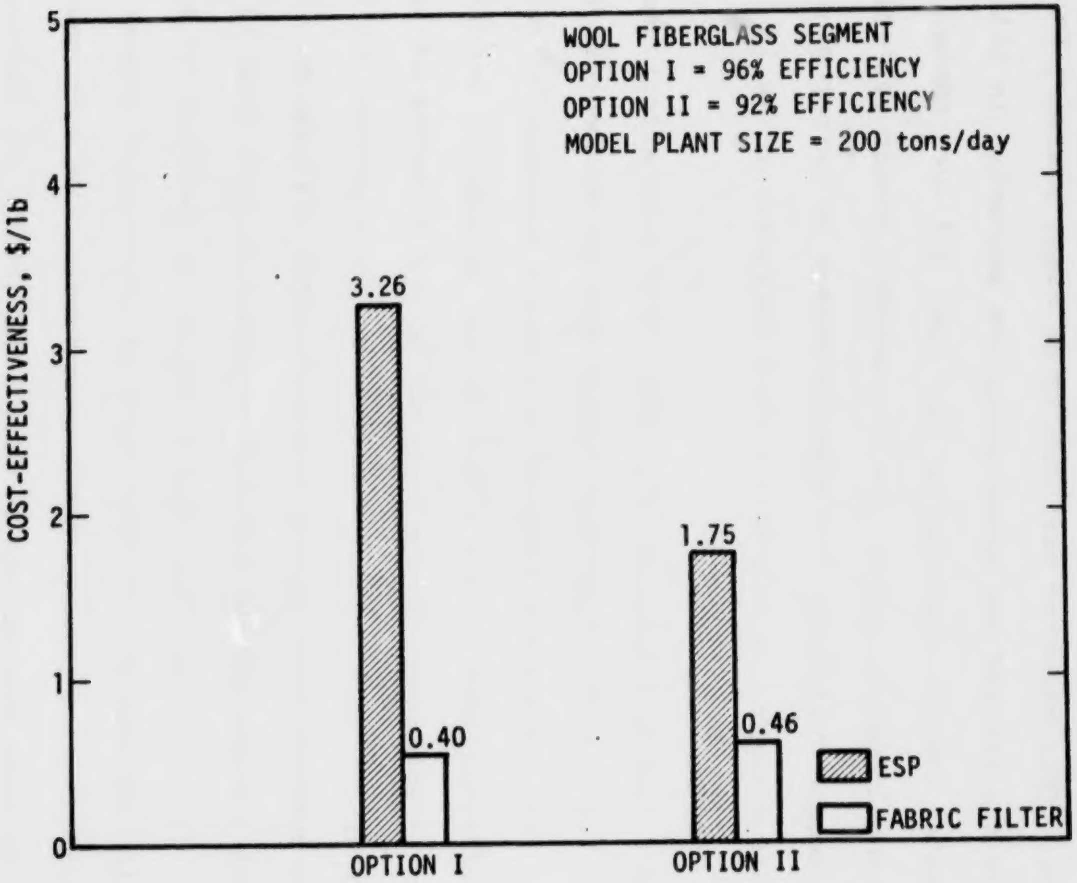

Figure 8-8. Cost-effectiveness of control options for the Wool Fiberglass segment.

The variation in cost-effectiveness between industry segments is due mainly to the changing SIP efficiency. It can be seen in Figures 8-9 and 8-10 that the results do not follow the expected pattern of increasing cost-effectiveness (lower cost-effectiveness ratio) with larger plant size and less restrictive control. This expected pattern can be seen, however, in Figure 8-7 for the Pressed and Blown: soda-lime segment. In this particular case, the SIP baseline is very low, and even though the incremental cost is large, the incremental pounds collected are also large. Therefore, the cost advantage of larger plant size and less restrictive standard is not overshadowed as it is in the other cases.

The fabric filter options show lower cost-effectiveness ratios for the more stringent regulatory option because significantly more pounds are removed at a small increase in cost. The cost-effectiveness of the fabric filter systems in regulatory Option II are based on the same air to cloth ratios as in regulatory Option I, but with the treatment of a portion of the gas stream corresponding to the lower required efficiency. The portion of the gas stream which is bypassed is less than 10 percent. It is likely that this would not be feasible in actual practice because of the difficulty of maintaining proper flow proportioning as furnace conditions change. In such cases, it would be more appropriate to treat the entire gas stream. Consequently, the Option II cost-effectiveness ratios in these cases are not meaningful.

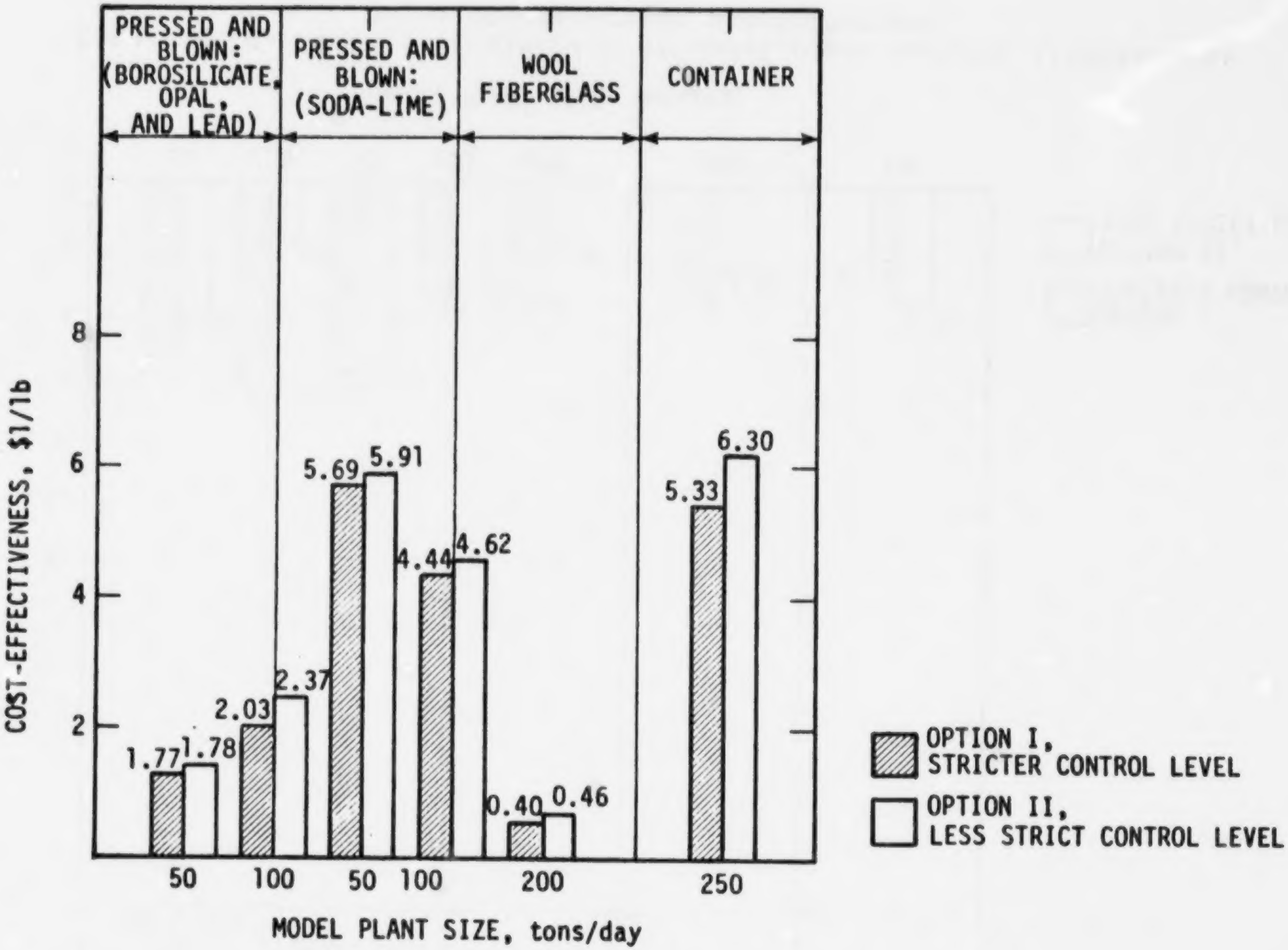

Figure 8-9. Cost-effectiveness of model plant control alternatives using fabric filters.

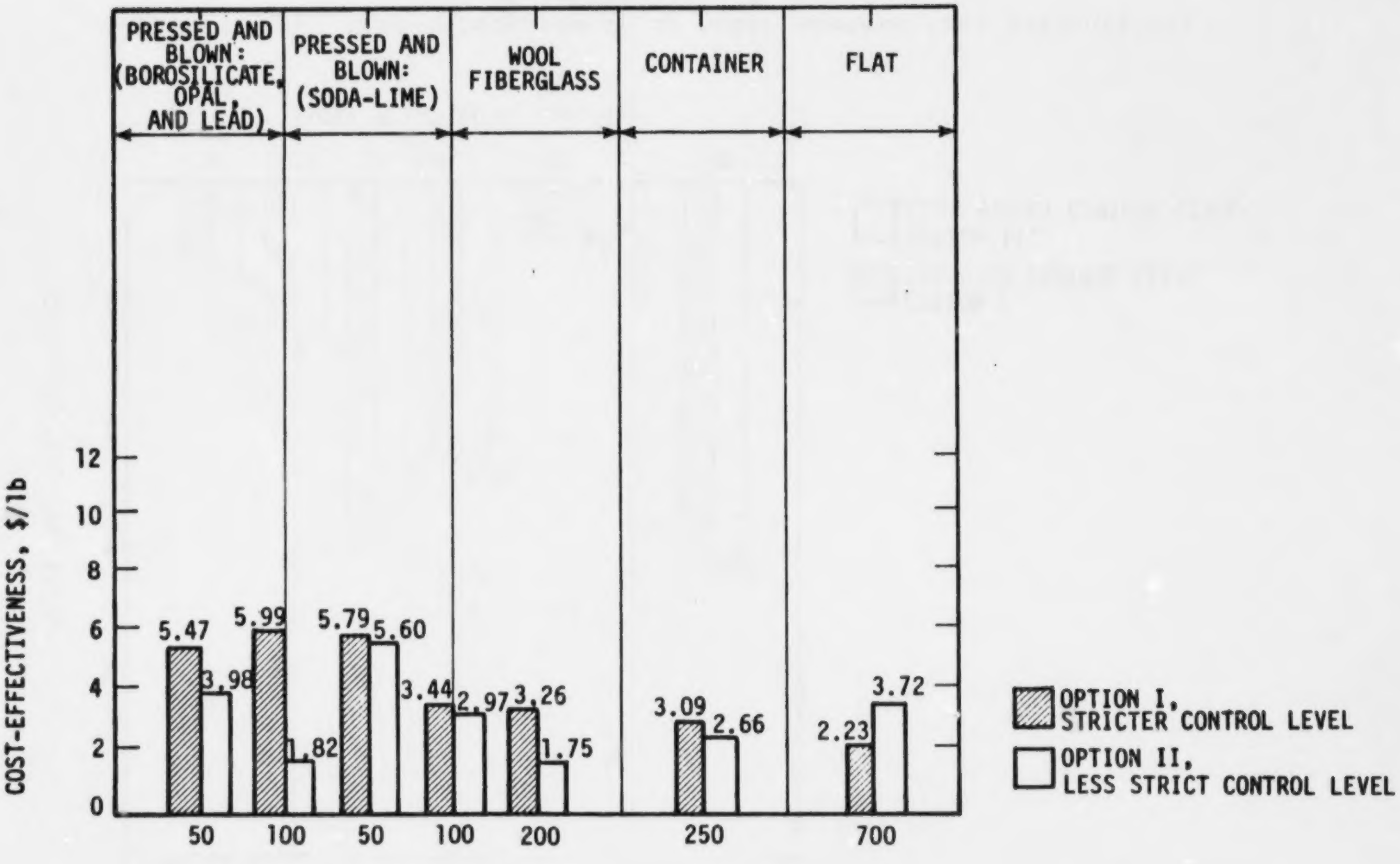

Figure 8-10. Cost-effectiveness of model plant control alternatives using electrostatic precipitators.

In the wool fiberglass segment using a fabric filter, the SIP baseline costs are also based on the concept of treating a portion of the stream. For the same reason stated above, the incremental cost of the regulatory options over and above the baseline is not meaningful.

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8.3 OTHER ENVIRONMENTAL COST CONSIDERATIONS

Water pollution control is the only other set of environmental regulations with any potential economic impact upon the glass manufacturing industry.* Impact in the case of new grassroots plants is defined as incremental control costs over those faced at existing plants. The increment for water pollution control consists of added costs for moving from best practicable controls, required of plants in 1977, to more stringent new source performance standards (NSPS). EPA defines NSPS requirements for the various glass manufacturing categories as being the same as best available controls with which existing plants must eventually be in compliance.

Wastewater containing various contaminants is present in all the glass manufacturing industries herein analyzed. However, the contaminants differ by industries and there are different wastewater generating processes in the industries. In general, the processes that generate wastewater are: etching; abrasive polishing; acid polishing; washing; rinsing; cullet and reject quenching; fume scrubbers; edge grinding; shear-spraying; cutting; and annealing. Considerable amounts of non-contact cooling water are also used in most of the industries.

Contaminants present in most wastewater include suspended solids, dissolved solids, oil and oxygen demanding wastes. Flourides are also present in the wastewaters of TV tube, hand pressed and blown glass, and incandescent bulb facilities that employ acid etching and polishing operations. Lead contaminants are present in the TV tube and hand-made pressed and blown glass facilities.

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*Existing OSHA Standards on lead and arsenic also affect the industry to a very minor extent. It is not known how the silica and lead standards presently being proposed, will impact on the industry.

Wastewater treatment methods to meet NSPS requirements vary considerably as a function of pollutant, glass manufacturing industry, and definition of best practicable controls. In one industry, wool fiberglass, BPT already specifies no discharge, therefore, no increment for NSPS is entailed. For the other industries incremental control usually consists of either diatomaceous earth or sand filtration. A few segments also require the addition of gravity oil separators, dissolved air flotation and activated alumina filtration.

Incremental water pollution control costs to meet NSPS have been expressed in Table 8-22 as a percent of product price in order to present a measure of economic impact. Two segments with percentages of 1% or greater are: incandescent bulbs (1.0%) and hand-made pressed and blown (2.1%). The size plant for which incremental water pollution control costs for the incandescent bulb industry were available was 175 tons per day capacity. Minimum-size new incandescent bulb plants are expected to be 400 tons per day. Due to expected economies of scale in a larger size plant, the acutal percentage of costs to product price is expected to be lower than the 1.0% mentioned above.

The 2.1% figure for hand-made pressed and blown was for a 5 TPD plant as compared to the 50 TPD model plant of the air pollution NSPS impact analysis. The water pollution economic analysis for hand-pressed and blown concluded that many existing plants of the size studied (5 TPD) would close. Such a conclusion appears to justify the selection of a 50 TPD plant as the minimum size new source. At the greater size, the control cost percentage of product price should be considerably lower than the 2.1% for the 5 TPD plant. The

Table 8-22

GLASS MANUFACTURING WATER POLLUTION CONTROL COSTS (INCREMENT OF NSPS OVER BPT)

Manufacturing Segment	Model Size Plant (TPD)	Incremental Cost as % of Selling Price(1)
Flat Glass	700	.5%
Wool Fiberglass	200	0(3)
Container	500	.4
Textile Fiberglass	100	N.A.
Pressed and Blown		
Machine Consumerware	50 100	N.A.(4) N.A.(4)
TV Tubes	100	.1
Optical	50	N.A.(4)
Incandescent	175(2) 100	1.0 N.A.
Hand-made Consumerware	5(2) 50 100	2.1 N.A. N.A.
Tubing	100	.2
Flourescent	100	N.A.(4)

(1)At the time that studies were performed, which assumes that control costs and product price have increased at the same rate.

(2)Available water pollution control costs for different size plant than modeled in air pollution NSPS.

(3)BPT requirements specify no discharge.

(4)Considered likely to have control costs impact within the same range as the other pressed and blown glass categories.

Sources: EPA Development Documents for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Insulation Fiberglass, Flat Glass and Pressed and Blown Glass Segments of the Glass Manufacturing Point Source Category.

discounted cash flow analysis in Section 8.4 for the hand-pressed and blown category suggests that the lower NSPS incremental water pollution control costs, when coupled with NSPS air pollution controls, would not deter investment in new plants.

8.4 ECONOMIC IMPACT ASSESSMENT

8.4.1 Summary

The purpose of this section is to measure the potential economic effects of imposing NSPS-controls on new primary glass plants. As used in the context of this document, the term "potential economic effects", refers to the extent to which new grassroots plant construction would be impeded in the industry if NSPS controls were mandatory.

A model plant approach was used to test the hypothesis that the addition of NSPS controls would not affect the rate of return on assets sufficiently to deter new grassroots plant construction in the glass industry.

Annualized control costs per ton of glass produced were calculated for 19 model plants, representing distinguishable segments of the glass industry. These costs were then divided by the average selling price of the industry's product to derive the unit price increase that might have occurred in that industry's product had the NSPS annualized control costs been passed through to the consumer.

This price increase was used as the criterion in a discriminant analysis procedure that separated the industry model plants into two categories. For each plant in the first category, the relative change in anticipated return on assets was computed by multiplying the estimated change by the plant's sales-to-assets ratio. If the relative change was no more than 10% of the anticipated rate of return on assets, and the absolute rate of return on assets was greater than 10% after the relative change was considered, the imposition of NSPS controls was considered to have no adverse effect on the new plant construction decision.

Plants in the second category were subjected to an additional screening process, which resulted in some plants being eliminated as non-representative of typical new plants, sources, other plants being reclassified into the first category, and the remaining plants being subjected to a discounted cash flow analysis, the results of which was used to substantiate or disprove the economic feasibility of constructing new grassroots plants in which NSPS controls were mandatory.

The findings of this study are that the imposition of NSPS controls will not adversely affect new plant construction in the glass industry.

8.4.2 Methodology and Application

As an instrument for measuring the potential economic effects of imposing NSPS controls on new primary glass plants, plant models were developed for the following industries: flat glass, container glass, wool fiberglass, textile fiberglass, machine-made consumer ware, hand-made consumer ware, TV envelope tubes, incandescent bulb blanks, optical glass and tubing. These models were developed by (1) accepting certain production parameters from Section 8.2 and (2) by assigning to the respective plant model other pertinent characteristics considered representative of grassroots new plants in that industry.

The production parameters accepted from Section 8.2 were production

Table 8-23

DATA SOURCES FOR MODEL-PLANT CHARACTERISTICS

Plant Characteristics	Data Source
Plant Investment	Industry Representatives Glass Packaging Institute
Average Product Price	Department of Commerce Industry Representatives Glass Packaging Institute
Production Capability of Typical New Plant	Industry Representatives Glass Packaging Institute
Profit Rates	Annual Reports
Working Capital	Almanac of Business and Industrial Financial Ratios Industry Representatives Glass Packaging Institute
Debt to Equity Rates	Annual Reports Industry Representatives Glass Packaging Institute
Anticipated Rate of Return on Assets	Industry Representatives Glass Packaging Institute "Energy, Efficiency Improvement Target for SIC 32: Stone, Clay, and Glass Products", Federal Energy Administration, June, 1976
Effective Product Yield	Industry Representatives Glass Packaging Institute

capability and the number of operating days per year. Other pertinent characteristics, such as working capital and average product price, were derived from the data sources outlined in Table 8-23. In some cases, industry models were developed for more than one production capability and/or more than one type of glass.

Several important assumptions were an integral part of the plant model for each industry:

1. The plant would include SIP controls as a matter of course;
2. Each plant so equipped with SIP controls would be considered economically feasible; that is, it would generate sufficient internal cash flow to justify the initial capital investment and achieve a minimum acceptable rate of return;
3. External financing for the incremental capital needed to comply with the proposed NSPS standard would be available;
4. No monetary resources other than those generated by the new facility could be used to meet NSPS annualized control costs;* and,
5. NSPS control costs would not be passed on to the consumer.

Model plants were used to test the hypothesis that the addition of NSPS control costs would not affect the rate of return on assets sufficiently to deter new plant construction.

NSPS control costs from Section 8.2 were examined, and the most costly control option for each industry was selected in order to measure the maximum

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*In the context of this analysis, NSPS control costs are defined as only the incremental costs above SIP control costs.

Table 8-24

SELECTED CONTROL COST ESTIMATES FOR NEW GRASSROOTS GLASS PLANTS*

Industry	Production Capability of Plant Model (TPD)	Type of Control Device	Capital** Cost of Control Device (1,000's$)*	Total ** Annualized Control Costs (1,000's $)
Flat Glass	700	ESP	$605	$190
Container Glass	250	Fabric Filter	1157	351
Wool Fiberglass	200	ESP	504	154
Textile Fiberglass	100	ESP	797	245
	50	ESP	759	226
TV Envelope Tubes	100	ESP	797	245
	50	ESP	759	226
Incandescent Bulb Blanks (Soda Lime)	100	Fabric Filter	767	228
	50	Fabric Filter	738	227
Incandescent Bulb Blanks (Borasilicate)	100	ESP	797	245
	50	ESP	759	226
Optical Glass	100	ESP	797	245
	50	ESP	759	226
Hand-made Consumer Ware	100	ESP	797	245
	50	ESP	759	226
Machine Consumer Glassware	100	ESP	797	245
	50	ESP	759	226
Tubing (Borasilicate)	100	ESP	797	245
	50	ESP	759	226

*Where options were available, the highest cost components were used in order to simulate a worst-case situation.

**Both sets of costs, in the context of this analysis, are defined as the incremental costs above SIP control costs.

possible change in the rate of return on assets. These options and the corresponding capital and annualized costs are shown for each industry in Table 8-24.

A discriminant analysis procedure was developed and applied as the next step in discerning whether the change in the rate of return on assets appeared to be of sufficient magnitude to adversely influence new plant construction decisions. The criterion used in the analysis procedure was the magnitude of the profitability on sales change produced from the absorption of NSPS annualized control costs. (This would be referred to as potential product price increase if costs would be passed through to the consumer.) This profitability change was derived by dividing the estimated control costs per ton of glass produced* by the average selling price of the industry's product.**

The results of the discriminant analysis are shown in Table 8-25. As can be seen, two industry categories were derived: Category I, containing those industries for which the estimated profitability change was 1% or less; the second, containing those for which the estimated profitability change was more than 1%.

For industries in Category I, the relative change in anticipated return on assets was computed by multiplying the estimated price change by the plant's sales-to-asset ratio. If the relative change was no more than 10% of the anticipated rate of return, and the absolute rate of return

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$$\text{*Estimated control cost per ton} = \frac{\text{Total Annualized Control Costs}}{\text{No. of TPY at capacity, adjusted for effective yield}}$$

**Average selling price, as used here, represents the net sales value per ton, f.o.b. plant, and excludes discounts and allowances.

Table 8-25

DISCRIMINANT ANALYSIS RESULTS

Category I

Industry	Model Plant Capability (TPD)	Control Cost/Ton Price/Ton
Flat Glass	700	.4%
Wool Fiberglass	200	.3%
Textile Fiberglass	100	.7%
Machine-made Consumer Ware	100	.3%
	50	.6%
TV Envelope Tubes	100	.7%
Tubing	100	.8%
Optical Glass	100	.1%
	50	.2%
Hand-made Consumer Ware	100	.8%

Category II

Industry	Model Plant Capability (TPD)	Control Cost/Ton Price/Ton
Container Glass	250	1.8%
Textile Fiberglass	50	1.4%
Incandescent Bulb Blanks (Soda-Lime)	100	1.5%
	50	3.0%
Incandescent Bulb Blanks (Borasilicate)	100	1.1%
	50	2.2%
Tubing	50	1.5%
Hand-made Consumer Ware	50	1.5%
TV Envelope Tubes	50	1.4%

was greater than 10% after the relative change was considered, the imposition of NSPS control costs was considered to have no adverse effect on the new plant construction decision.

Industries in Category II were subjected to an additional screening process. Production capability of the "typical" new grassroots plant for each industry was compared with that of the industry's model plant found in Category II. If the production capability of the typical plant was equal to that of the model plant (as was true in the case of the hand-made consumer ware 50 TPD facility), the calculated profitability change for the model plant was accepted. If the production capability of the typical plant was greater than that of the model plant, Category I was re-examined for larger plants of the same industry. A larger plant was listed in the cases of the textile fiberglass 50 TPD facility, the tubing 50 TPD facility, and the TV envelope tube 50 TPD facility; accordingly, the Cateogry II model was eliminated for these industries and further analysis of that industry was limited to the model found in Category I. If no larger plant was listed in Category I, the production parameter of the highest volume model plant for that industry in Category II was adjusted, and the appropriate control costs were scaled to permit the recalculation of the profitability change. This was true in the case of the container glass 250 TPD facility, the incandescent soda-lime bulb blank 100 TPD facility, and the incandescent borasilicate bulb blank 100 TPD facility. The lower-volume model plants for the incandescent bulb blank industry in Category II were eliminated from further consideration. (See Table 8-26).

If the recalculated profitability change shown in Table 8-26 was 1% or less (as was true of the incandescent soda-lime bulb blank 100 TPD facility and the incandescent borasilicate bulb blank 100 TPD facility), the model

Table 8-26

SCALED CONTROL COSTS AND RECALCULATED PRICE INCREASES

Industry	Production Capability of Model Plant as originally stated (TPD)	Production Capability of Typical New Plant (Restated Capability of Model Plant)	Scaled Capital Costs of Control Device*	Scaled Annualized Control Costs*	Recalculated Price Increase**
Container	250	500	$2,000,000	$515,000	1.3%
Incandescent Soda-Lime Bulb Blanks	100	400	$ 920,000	$504,600	.73%
Incandescent Bora-silicate Bulb Blanks	100	400	$ 800,000	$264,000	.3%

*These costs are defined as the incremental costs above SIP control costs.

**The recalculated price increase was computed using the same price increase formula given on page 8-97.

Table 8-27

CHANGES IN RATE OF RETURN ON ASSETS AFTER THE IMPOSITION OF NSPS CONTROLS

	Revenue of Model Plant (Millions $)	Assets*	Sales-To Assets-Ratio	Profitability Change	Rate of Return on Assets Before NSPS Controls	Change in Rate of Return On Assets After Controls
Flat Glass (700 TPD)	42.9	59.6	.72	.4%	15-20%	.3%
Wool Fiberglass (200 TPD)	52.2	56.8	.92	.3%	15-20%	.3%
Textile Fiberglass (100 TPD)	37.2	36.4	1.	.7%	15-20%	.7%
Machine-made Consumer Ware (100 TPD)	81.1	50.8	1.6	.3%	12-15%	.5%
Machine-made Consumer Ware (50 TPD)	40.6	50.8	.80	.6%	12-15%	.5%
Hand-made Consumer Ware (100 TPD)	30.0	20.5	1.5	.8%	12-15%	1.2%
TV Envelope Tubes (100 TPD)	33.9	50.8	.67	.7%	12-15%	.5%
Tubing (100 TPD)	29.4	50.8	.57	.8%	12-15%	.3%
Optical Glass (50 TPD)*	80.8	50.8	1.6	.2%	12-15%	.3%
Incandescent Soda-Lime Bulb Blanks	64.4	50.9	1.3	.7%	12-15%	.9%
Incandescent Borasilicate Bulb Blanks	86.6	50.8	1.7	.3%	12-15%	.5%
	(1)	(2)	(3)	(4)	(5)	(6)

Key: (1) ÷ (2) = (3)
(3) x (4) = (6)

*Includes fixed assets, working capital and NSPS capital.

plant was reclassified into Category I and the relative change in the rate of return on assets was computed as previously described. Table 8-27 shows the changes in rate of return on assets for the model plants falling into Category I, before and after the second screening. If the recalculated price increase shown in Table 8-26 remained greater than 1% (as was true in the case of the container glass 500 TPD facility), the plant remained in Cateogry II.

A discounted cash flow analysis (DCF) was then performed for each model plant found in Category II (the container glass 500 TPD facility and the hand-made consumer ware 50 TPD facility). The results of these analyses were used to substantiate or disprove the economic feasibility of grassroots new plants in which NSPS controls had been installed. These results are shown below in Tables 8-29, 8-30, and 8-31. Meanwhile, Table 8-28 of this section explains the discounted cash flow methodology used in those tables.

8.4.3 Findings

Table 8-27 shows the changes in the rate of return on assets for the model plants falling into Category I, before and after the second screening. As can be seen from this Table, the percentage change in the required rate of return for model plants in all industries fell within an acceptable range, i.e., was less than 10% of the rate of return on assets. It was, therefore, concluded that the imposition of NSPS controls would have no adverse effects on the new plant construction decision for the Category I model plants.

Tables 8-29, 8-30, and 8-31 show the discounted cash flows for the model plants that remained in Category II after the screening process was completed (two tables for the container glass 500 TPD facility and one

Table 8-28

DISCOUNTED CASH FLOW METHODOLOGY

Industry Assumptions		Data Requirements and Computational Steps
Container	Hand-made Consumer Ware	
$255	$5500	Revenue = Average Selling Price per Ton
15%	13.1%	Profit Before Tax and Before P.C. = Revenue x Profit Rate Before Taxes
Pollution Control Incremental Costs		Annualized Control Costs ÷ (Yearly Tonnage Capacity x Yield)
Profit Before Taxes and After Pollution Control		Profit Before Taxes and P.C. minus P.C. Incremental Costs
Taxes		48% of profit before taxes and after P.C.
Profit		Profit before taxes and after P.C. minus taxes
Investment Tax Credit (ITC)		10% x Equipment Cost (incl. P.C.) ÷ (Yearly Tonnage x Yield) (amount allocated in 1st and successive years no greater than tax owed)
Depreciation (years) Equip. 15 Bldg. 40	Equip. 15 Bldg. 33	(Equip. or Bldg. Value ÷ Number Depreciable Years) ÷ (Yearly Tonnage x Yield)
Interest		$\frac{10\% \times \text{Tax Rate } (48\%) \times \% \text{ Investment Funded by Debt} \times \text{Total Investment}}{\text{Yearly Tonnage} \times \text{Yield}}$
Debt Repayments 15 years 85% debt	15 years 50% debt	$\frac{\% \text{ Investment Funded by Debt} \times \text{Total Investment} \div 15 \text{ years}}{\text{Yearly Tonnage} \times \text{Yield}}$
Net Cash Flow		Profit + ITC + Depreciation + Interest minus Debt Repayments
Discount Rate 15% & 8%	15%	Minimum Acceptable Rate of Return on Equity or on Assets
Discounted Cash Flow		Net Cash Flow x Discount Rate
Initial Investment		Total Investment ÷ (Annual Tonnage & Yield) x % Equity or Debt Financed (Total Investment = Equip., Land, Bldgs., P.C. + working capital)
Present Value of Discounted Cash Flow		Sum of Discounted Cash Flows

Table 8-29

HAND-MADE CONSUMERWARE DISCOUNTED CASH FLOW

(50 TPD)

	Cost Per Ton of Glass Produced									
	1978	1979	1980	1981	1982	1983	....	1990	1991	1992
Price/Ton	$5550									
Profit Before Taxes & Before P.C. (13.1%)	727.1									
Pollution Control (Incremental)	83.6									
Profit Before Taxes & After P.C.	643.5									
Taxes	308.9									
Profit	334.6									
ITC	178.6									
Depr. - Bldgs.	70.6									
Depr. - P.C.	48.7									
Depr. - Equipment	75.4									
Interest x Tax	126.7									
Debt Repayments	175.2									
Net Cash Flow	659.4	480.8	480.8	480.8	480.8	480.8	...	480.8	480.8	2750.7(1)
Disc. Rate (15% A.T.)	.9286	.7993	.6879	.5921	.5096	.4386	...	.1535	.1321	.1137
Disc. Cash Flow	$612.3	384.2	330.7	284.7	245.0	210.9	...	73.8	63.5	312.8
Initial Equity Investment	$2262.5/Ton									
Present Value of Discounted Cash Flow - 15 years	$3291.3/Ton									

(1) Includes $1110 working capital recovery, $1130.3 undepreciated building and $29.6 recovered land value.

Table 8-30

CONTAINER GLASS MID-RANGE ESTIMATES[1] DISCOUNTED CASH FLOW

(500 TPD)

	Cost Per Ton of Glass Produced							
	1978	1979[2]	1980	1981	1982	1983 1990	1991	1992
Price/Ton	$255	$255						
Profit Before Taxes & Before P.C. (15.0%)	38.3	38.3						
Pollution Control (Incremental)	3.8	3.4						
Profit Before Taxes & After P.C.	34.5	34.9						
Taxes	16.6	16.7						
Profit	17.9	18.2						
ITC	15.4	0						
Depr. - Bldgs.	1.5	1.4						
Depr. - Equipment incl. P.C.	13.0	11.7						
Interest x Tax	12.3	11.1						
Debt Repayments	17.1	15.4						
Net Cash Flow	43.0	27.0	27.0	27.0	27.0	27.0 .... 27.0	27.0	27.0
Disc. Rate (15% A.T.)	.9286	.7993	.6879	.5921	.5096	.4386 ... .1535	.1321	.1137
Disc. Cash Flow	$39.9	$21.6	$18.6	$16.0				
Initial Equity Investment	$40.8							
Present Value of Discounted Cash Flow	$40.8							

[1] As supplied by the Glass Packaging Institute.

[2] Difference in 1979 (and succeeding years) from 1978 is the difference in 1st year yield of new plant.

Table 8-31

CONTAINER GLASS MID-RANGE ESTIMATES(1) DISCOUNTED CASH FLOW

(500 TPD)

	Cost Per Ton of Glass Produced				
	1978	1979(2)	1980	1981	1982......
Price/Ton	$255	$255			
Profit Before Taxes & Before P.C. (15%)	38.3	38.3			
Pollution Control (Incremental)	3.8	3.4			
Profit Before Taxes & After P.C.	34.5	34.9			
Taxes	16.6	16.7			
Profit	17.9	18.2			
ITC	15.4	0			
Depr. - Bldgs.	1.5	1.4			
Depr. - Equipment, incl. P.C.	13.0	11.7			
Interest x Tax	12.3	11.1			
Debt Repayments	17.1	15.4			
Net Cash Flow	$43.0	25.0	19.4	17.2	17.2......(3)
Disc. Rate (8% A.T.)	.9610	.8872	.8189	.756	.6979......
Disc. Cash Flow	$41.3	$24.0	$22.1	$20.4	$18.8......
Initial Investment	$265.8				
Present Value of Discounted Cash Flow (20 years)	$303.2				

(1) As supplied by the Glass Packaging Institute.

(2) Differences from 1979 and beyond arise because of lower yield at plant start-up.

(3) Values for year 20 include $29.1/ton working capital recovery, $8.9/ton land value and $20.8/ton undepreciated bldg. value.

table for the hand-made consumerware 50 TPD facility). The DCF analysis for the hand-made consumerware industry utilizes the rate of return on equity as the discount rate rather than the rate of return on assets. When such a rate is used (which is usually higher than the return on assets) the net present value is compared to the equity portion of the investment rather than being compared to the entire investment, which would be the case when discounting with the return on assets. The choice of the equity rate of return was made since ownership of small plants in this industry is typically private, and such a rate is considered their minimum acceptable return. The sum of the discounted cash flows exceeds the equity investment, and it is, therefore, concluded that NSPS-controls would not adversely affect new plant construction decisions in the hand-made consumerware industry.

The same conclusion is reached for the container industry. However, the data does not present as clear a picture as it did above. DCF calculations were performed using both, a rate of return on assets as compared to total asset investment, and a rate of return on equity as compared to the equity portion of the investment. The latter calculation clearly shows present value exceeding the equity investment utilizing a 15% after-tax return, and therefore not adversely affecting new plant construction. A significant factor in that outcome is the low equity investment of 15% specified by the industry and, therefore, a large amount of debt leveraging.

When an 8% minimum acceptable return on assets is used as the discount rate with the data supplied by the Glass Packaging Institute (GPI), the present value also exceeds that of the initial investment. GPI did not supply a before-tax profit rate on sales and the results of the DCF are quite sensitive to that rate. A rate of 15% was calculated based on the GPI minimum acceptable return on assets, and the sales to assets ratio for a new plant. The 15% profit rate before taxes is high as compared to the present rate on existing plants of about 8%. If an 8% before-tax rate had been used, the present value would be less than the initial investment. However, the 8% minimum return on assets rate supplied by GPI must convert to a 15% before tax profit rate in order for the 8% to be achieved, given the sales to assets ratio of the GPI data. A before-tax profit rate that is higher than the rate which presently exists in the industry suggests that new plants are more capital intensive and provide improved earnings.

If such a rate is not achievable, it suggests that incentive is not present for new container plants of this size to be built, regardless of NSPS controls. The change in return on assets from NSPS controls is 13% at the 15%-before-tax profit rate, and 15% at the 8%-before-tax profit rate.

8.4.4 Capital Availability

In conducting the profitability change analysis and the discounted cash flow analysis used to test the economic feasibility of imposing NSPS controls on new primary glass manufacturing plants, the assumption was made that capital would be available. This section turns to the examination of that assumption. Capital availability assessment is defined here as, the sufficiency of cash flow to permit the repayment of debt.

Model plants in Category I were estimated to be impacted by NSPS controls by a change in return on assets of less than 10%. Since such a change is relatively small and since the cash flow from profits is not the only cash flow available to service debt obligations, it is concluded that financing could be obtained by those plants for NSPS.

For plants that remained in Category II after screening, the increase in capital required to install NSPS controls for the two model size plants subjected to a DCF analysis are:

50 TPD	Hand-Made Consumerware	5.7%
500 TPD	Container Glass	10.0%

Since the DCF analyses included provisions for all debt repayment and since the cash flows in the analyses exceeded the initial investment at the minimum acceptable rate, it is also concluded that sufficient cash flows exist in those plants for the NSPS capital-related costs.

8.4.5 Industry Costs

Table 8-32 presents the maximum number of typical new plants which will be constructed in each of the industry segments during the five-year period from 1978 to 1982. These projections are based on current forecasts of industry growth which have been applied to 1977 shipment statistics and the results converted to new plant estimates based on typical new plant production parameters. A methodology, described in 8.1.6.7, was used to project demand in the pressed and Blown segment. These estimates assume (1) no excess practical capacity existed in any of the industry segments in 1977, and (2) that all industry growth requirements will be satisfied through the construction of grassroots new plants. To the extent that 1977 shipments in any segment were less than maximum practical capacity, the number of new sources will have been overstated, and the industry cost estimates inflated.

Table 8-32

NEW SOURCES: FIFTH-YEAR ANNUALIZED COSTS

Industry Segment	Production Capability of New Plant (TPD)	No. of New Sources Required	Expected Growth Rate (%)	5th Year Annualized Costs ($000's)
Flat Glass	700	2	4.2	380
Container Glass	500	7	2.2	3,605*
Wool Fiberglass	200	7	6.0	1,078
Textile Fiberglass	100	5	9.0	1,225
Machine-Made Consumerware	300	1	4.0	529*
Tubing Glass	200	2	4.0	796*
TV Envelope Tubes	400	1	4.0	647*
Incandescent Bulb Blanks	400	1	4.0	504
Optical Glass	50	2	4.0	452
Hand Pressed and Blown Glass	50	2	4.0	452

*These costs were scaled from those presented in Section 8-2, to accommodate the production capability of the typical new plant.

Table 8-32 presents the maximum total annualized control costs that will have been incurred by each industry by 1983 if NSPS controls are installed on all grassroots new plants. These totals were derived by multiplying the estimated number of new sources for each industry by the appropriate annualized control cost estimate. As Table 8-32 shows, the container glass industry will experience greater costs than any other industry segment.

Neither the total annualized control costs for all industry segments nor the total control costs per ton as a percentage of selling price are considered a major economic consequence as specified by the regulatory analysis requirement of Executive Order 12044.

APPENDIX A

EVOLUTION OF STANDARDS

APPENDIX A

EVOLUTION OF STANDARDS

Date	
06/77	Conducted a literature search to acquire reference materials
07/77	Contacted EPA regional offices and 26 state agencies
	Contacted various control equipment vendors
	Visited New Jersey Bureau of Air Pollution Control, EPA Region II and III offices and SCAQMD
08/77	Contacted industry representatives to update plant data
	Meeting with EPA and ad-hoc committee of GPI
09/77	PES visited five glass manufacturing facilities in the western U.S.
	PES and the task manager together, visited four glass manufacturing facilities in the eastern and central U.S.
	Commenced the drafting of the SSEIS introductory chapter
10.77	Brinks mist eliminator pilot study received and reviewed
	Received test reports from New Jersey
	PES visited one glass manufacturing facility
	Sent out eight, 114 Questionnaires
12/77	PES witnessed an EPA Method 5 test
	Progress meeting with EPA
01/78	Received final 114 Questionnaire response
02/78	Working Group meeting to discuss findings of SSEIS and the recommended standard
	Commenced work on second draft of SSEIS
03/78	NAPCTAC package, consisting of the second draft of the SSEIS was submitted

04/78	NAPCTAC meeting held to review the recommended standard
04/78 to 01/79	SSEIS was reviewed and edited and the Preamble and Regulation were written for submission to the Steering Committee
07/78	Meeting with PPG representatives
11/78	Meeting with the ad-hoc committee of GPI to discuss the SSEIS and Regulation
12/78	Meeting with EPA in Durham to discuss progress of SSEIS
01/79	Steering Committee package submitted for comments on the proposed standard
02/79	Meeting with GPI representative to discuss the SSEIS as it went to the Steering Committee
03/79	Package submitted for AA Concurrence

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Standards Support and Environmental Impact Statement (BID)
1. Background and Description of Proposed Action	
Summary of Proposed Standards	The standards are summarized in chapter 1, section 1.1.
Statutory Basis for the Standard	The statutory basis for the standard is given in chapter 2.
Facility Affected	A description of the facility to be affected is given in chapter 3, section 3.1.
Process Affected	A description of the process to be affected is given in chapter 3, section 3.2.
Availability of Control Technology	Information on the availability of control technology is given in chapter 4.
Existing Regulations at State or Local Level	A discussion of existing regulations on the industry to be affected by the standards is included in chapter 3, section 3.2.
2. Alternatives to the Proposed Action	
No Action or Postponing Action	
Environmental Impacts	Environmental effects of not implementing the standards are discussed in chapters 3 and 7.
Costs	The costs of not implementing the standards are considered in chapter 8, section 8.1.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (continued)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Standards Support and Environmental Impact Statement (BID)
Health and Welfare Impact	The health/welfare impact of not implementing the standards is considered in chapter 7.
Option II	
Environmental Impacts	The environmental impacts associated with Option II emission control systems are considered in chapter 7.
Costs	The cost impact of Option II emission control systems is considered in chapter 8, section 8.2.
Health and Welfare Impact	The impact of Option II emission control systems on health and welfare is considered in chapter 7.
3. Environmental Impact of Proposed Action	
Air Pollution	The air pollution impact of the proposed standards is considered in chapter 7, section 7.1.
Water Pollution	The impact of the proposed standards on water pollution is considered in chapter 7, section 7.2.
Solid Waste Disposal	The impact of the proposed standards on solid waste disposal is considered in chapter 7, section 7.3.
Energy	The impact of the proposed standards on energy use is considered in chapter 7, section 7.4.
Costs	The impact of the proposed standards on costs is considered in chapter 8, section 8.2.

APPENDIX C

EMISSION MEASUREMENT

C.1 Emission Measurement Methods

During the standard support study for glass manufacturing plants, EPA conducted particulate emission tests at two facilities, one controlled with a baghouse, and the other with a scrubber. The tests were run in accordance with EPA Method 5 (40 CFR Part 60 - Appendix A). Method 5 provides detailed procedures and equipment criteria, and other considerations necessary to obtain accurate and representative particulate emission data. Visible emission data were taken during the two EPA tests in accordance with Method 9 (40 CFR Part 60 - Appendix A).

In addition to the Method 5 tests, particulate emission data were also obtained using proposed Method 17 at the plant controlled with a baghouse. Method 17, which was proposed in the Federal Register on September 24, 1976 (41 FR 42020), collects particulate samples on a filter located in the stack and the samples are, therefore, collected at stack temperatures, (in this case, 180°C). The Method 5 filter is located outside the stack and is maintained at a temperature of 120°C. The Method 17 samples obtained by EPA at a stack temperature of 180°C produced results 35 percent lower than the Method 5 tests run at a temperature of 120°C. These differences can be expected from stack emissions containing vapors that will condense between 180 and 120°C and this is considered the reason for the lower in-stack filter results.

The remaining data base was obtained from reports submitted by State agencies or glass manufacturing plants referenced in Chapter 4. The emission results in Reports 24, 32, 41, 43, and 44 were considered to be representative of Method 5 testing. The emission results in Reports 25 and 31 were obtained by collecting samples with water impingement followed by filtration. The water impingement method should collect more condensable stack gas components and reactive gases than Method 5, therefore, the reported results are considered to be higher than would be measured by Method 5.

C.2 Monitoring Systems

The opacity monitoring systems that are adequate for other stationary sources, such as steam generators, covered by performance specifications contained in Appendix B of 40 CFR 60 Federal Register, Ocotber 6, 1975, should also be applicable to glass manufacturing plants except where condensed moisture is present in the exhaust stream. When wet scrubbers are used for emission reduction from glass plants, monitoring of opacity is not applicable and another parameter such as pressure drop may be monitored as an indicator of emission control.

Equipment and installation costs for visible emissions monitoring are estimated to be about $18,000 to $20,000 per site. Annual operating costs, which include the recording and reducing of data, are estimated at about $8,000 to $9,000 per site. Some savings in operating costs may be achieved if multiple systems are used at a given facility.

C.3 Performance Test Methods

Consistent with the data base upon which the new source standards have been established, the recommended performance test method for particulate matter is Method 5 (Appendix A - 40 CFR 60, Federal Register, December 23, 1971). In order to perform Method 5, Methods 1 through 4 must also be used. Method 17 (in-stack filter method) is not recommended as the performance test because of the presence of condensable components and variable stack gas temperatures. For glass plant emissions, in-stack filtration does not provide for a consistent definition of particulate matter and does not allow for the comparison of the various systems of control (e.g., baghouses and scrubbers).

Subpart A of 40 CFR 60 requires that affected facilities which are subject to standards of performance for new stationary sources must be constructed so that sampling ports, adequate for the required performance tests, are provided. Platforms, access, and utilities necessary to perform testing at those ports must also be provided.

Sampling costs for performing a test consisting of three Method 5 runs is estimated to range from $5,000 to $9,000. If in-plant personnel are used to conduct tests, the costs will be somewhat less.

The recommended performance test method for visible emissions is Method 9 (Appendix A - 40 CFR 60, Federal Register, November 12, 1974).

APPENDIX D

PRIMARY GLASS MANUFACTURERS

APPENDIX D
PRIMARY GLASS MANUFACTURERS

State	SIC Code	Manufacturer	Plant Location
Alabama	3221	Brockway Glass	Montgomery
Arkansas	3211	Fourco Glass	Ft. Smith
	3221	Arkansas Glass Container	Jonesboro
	3229	Thomas Industries, Inc.	Ft. Smith
California	3211	C-E Glass	Fullerton
	3211	Guardian Industries	Torrance
	3211	Libby-Owens-Ford	Lathrop
	3211	PPG	Fresno
	3221	Ball Corporation	El Monte
	3221	Brockway Glass	Oakland
	3221	Brockway Glass	Pomona
	3221	Gallo Glass	Modesto
	3221	Glass Containers	Antioch
	3221	Glass Containers	Hayward
	3221	Glass Containers	Vernon
	3221	Madera Glass Div. of Indian Head	Madera
	3221	Kerr Glass	Santa Ana
	3221	Latchford Glass	Los Angeles
	3221	Latchford Glass	San Leandro
	3221	Latchford Glass	Huntington Park
	3221	Owens-Illinois	Los Angeles
	3221	Owens-Illinois	Oakland
	3221	Owens-Illinois	Tracy
	3221	Thatcher Glass	Saugus
	3229	Arrowhead Puritas Water	Gardena
	3229	Brock Glass	Santa Ana
	3229	The Glass Works	Huntington Beach
	3229	Libby Glass Division of Owens-Illinois	City of Industry
	3229	Ray Lite-Glass	South Gate
	3296*	Johns-Manville	Corona
	3296*	Johns-Manville	Willows
	3296*	Owens-Corning-Fiberglass	Santa Clara
	3229*	Reichold Chemical	Irwindale
Colorado	3221	Columbine Glass	Wheatridge
	3229	Pikes Peak Glass	Colorado Springs
Connecticut	3221	Glass Containers	Dayville
	3229	Innotech	Trumbell
	3229	Thermos Division of Kings - Seeley Thermos	Norwich
	3229	Thermos Division of Kings - Seeley Thermos	Taftville

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Florida	3211	Guardian Industries	Ft. Lauderdale
	3221	Anchor Hocking	Jacksonville
	3221	Owens-Illinois	Lakeland
	3221	Industrial Glass	Bradenton
	3221	Thatcher Glass	Tampa
Georgia	3221	Glass Containers	Forest Park
	3221	Midland Glass	Warner Robins
	3221	Owens-Illinois	Atlanta
	3296*	Certain-Teed Products	Athens
	3296*	Johns-Manville	Winder
	3296*	Owens-Corning Fiberglass	Fairburn
Illinois	3211	Libbey-Owens-Ford	Ottawa
	3211	PPG	Mt. Zion
	3221	Anchor Hocking	Gurnee
	3221	Ball Corporation	Mundelein
	3221	Hillsboro Glass	Hillsboro
	3221	Obear-Nestor Glass Div. of Indian Head Inc.	St. Louis
	3221	Obear-Nestor Glass Div. of Indian Head Inc.	Lincoln
	3221	Kerr Glass	Plainfield
	3221	Metro Containers	Dolton
	3221	National Bottle Corporation	Joliet
	3221	Owens-Illinois	Alton
	3221	Owens-Illinois	Streator
	3221	Thatcher Glass	Streator
	3229	Eire Glass	Park Ridge - 3 Plants
	3229	Johnson Glass and Plastic Corporation	Chicago
	3229	Kimble Div. of Owens-Illinois	Chicago Heights
	3229	Peltier Glass	Ottawa
	3229	Reha Glass	Chicago
	3296*	Johns-Manville	Waukegan
Indiana	3221	Anchor Hocking	Winchester
	3221	Brockway Glass	Lapel
	3221	Foster-Forbes	Marion
	3221	Glass Containers	Gas City
	3221	Glass Containers	Indianapolis
	3221	Kerr Glass	Plainfield
	3221	Midland Glass	Terre-Haute
	3221	Owens-Illinois	Gas City

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Indiana (cont.)	3221	Thatcher Glass	Lawrenceburg
	3229	Canton Glass	Hartford City
	3229	Corning Glass	Bluffton
	3229	Indiana Glass	Dunkirk - 2 Plants
	3229	Kokomo Opalescent Glass	Kokomo
	3229	Kimble Div. of Owens-Illinois	Warsaw
	3229	St. Clair Glass Works	Elwood
	3229	Sinclair Glass	Hartford City
	3296*	Certain-Teed	Shelbyville
	3296*	Johns-Manville	Richmond
Kansas	3296*	Certain-Teed Products	Kansas City
	3296*	Certain-Teed Products	Wichita Falls
	3296*	Johns-Manville	McPherson
	3296*	Owens-Corning Fiberglass	Kansas City
Kentucky	3229	Corning Glass	Danville
	3229	Corning Glass	Harrodsburg
	3229	General Electric	Lexington
	3229	General Electric	Somerset
	3229	GTE-Sylvania	Verseilles
	3229	Venezian Art Glass	Callettsburg
Louisiana	3221	Laurens Glass Division of Indian Head	Ruston
	3221	Owens-Illinois	New Orleans
	3221	Underwood Glass	Harahan
	3229	Libbey Glass Division of Owens-Illinois	Shreveport
Maryland	3211	PPG Industries	Cumberland
	3221	Chattanooga Glass	Baltimore
	3221	Columbia Glass	Baltimore
	3221	Carr-Lowrey Division of Anchor Hocking	Baltimore
	3229	Anchor Hocking	Baltimore
	3229	Kimble - Terumo Division of Owens-Illinois	Elkton
Massachusetts	3211	Guardian Industries	Webster
	3221	Foster-Forbes	Milford
	3221	Owens-Illinois	Mansfield
	3229	American Optical	Southbridge - 2 plants
	3229	Emerson And Cuming	Canton
	3229	GTE Sylvania	Danvers
	3229	GTE Sylvania	Ipswich

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Michigan	3211	Ford Motor Company	Dearborn
	3211	Guardian Industries	Carleton
	3211	Guardian Industries	Detroit
	3221	Owens-Illinois	Charlotte
Minnesota	3221	Brockway Glass	Rosemount
	3221	Midland Glass	Shakopee
Mississippi	3221	Chattanooga Glass	Gulf Port
	3221	Chattanooga Glass	Mineral Wells
	3221	Glass Containers	Jackson
	3229	Ferro Corporation	Flowood
	3229	General Electric	Jackson
Missouri	3211	C - E Glass	Saint Louis
	3211	PPG Industries	Crystal City
	3229	Pittsburg Corning Corporation	Sedalia
New Hampshire	3229	GTE Sylvania	Greenland
New Jersey	3211	C - E Glass	Cinnaminson
	3221	Anchor Hocking	Salem
	3221	Brockway Glass	Freehold
	3221	Kerr Glass	Millville
	3221	Leone Industries	Bridgeton
	3221	Metro Containers	Jersey City
	3221	Metro Containers	Carteret
	3221	Midland Glass	Cliffwood
	3221	Owens-Illinois	Bridgeton
	3221	Owens-Illinois	North Bergen
	3221	Thatcher Glass	Wharton
	3221	Wheaton Glass	Millville
	3229	Friedrich and Dimmock	Millville
	3229	Kimble Division of Owens-Illinois	Vineland
	3229	Potters Industries	Carlstadt
	3229	Thermal American Fused Quartz	Mintville
	3229	Wheaton Glass	Millville - 2 plants
	3229	Wheaton Products	Millville
	3296*	Certain-Teed Products	Berlin
	3296*	Johns-Manville	Berlin
	3296*	Owens-Corning-Fiberglass	Barrington
New York	3221	Glenshaw Glass	Orangeburg
	3221	Leone Industries	Rochester
	3221	Owens-Illinois	Brockport
	3221	Thatcher Glass	Elmira
	3229	American Optical	Buffalo

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
New York (continued)	3229	Bausch And Lomb	Rochester
	3229	Corning Glass	Corning - 4 plants
	3229	Eastman Kodak	Rochester
	3229	Gillinder Brothers	Port Jervis
	3229	Warren L. Kessler	Bethpage
	3229	Super Glass	Brooklyn
	3296*	Owens-Corning Fiberglass	Delmar
North Carolina	3211	Libbey-Owens-Ford	Laurinburg
	3221	Ball Corporation	Asheville
	3221	Laurens Glass Division of Indian Head	Henderson
	3221	Owens-Illinois	Winston-Salem
	3229*	PPG Industries	Lexington
	3229*	PPG Industries	Shelby
	3229*	United Merchants	Statesville
Ohio	3211	Guardian Industries	Millbury
	3211	Guardian Industries	Upper Sandusky
	3211	Libbey-Owens-Ford	East Toledo
	3211	Libbey-Owens-Ford	Rossford
	3221	Brockway Glass	Zanesville
	3221	Chattanooga	Mount Vernon
	3229	Anchor Hocking	Lancaster - 2 plants
	3229	E. O. Brody	Cleveland
	3229	Corning Glass	Greenville
	3229	Crystal Art Glass	Cambridge
	3229	Federal Glass	Columbus
	3229	General Electric	Willoughby
	3229	General Electric	Logan
	3229	General Electric	Bucyrus
	3229	General Electric	Niles
	3229	General Electric	Cleveland
	3229	Guernsey Glass	Cambridge
	3229	Labind Glass	Grand Rapids
	3229	Lancaster Glass	Lancaster - 2 Plants
	3229	Imperial Glass Corporation, a subsidiary of Lennox Crystal, Incorporated	Bellaire
	3229	Libbey Glass Division of Owens-Illinois	Toledo
	3229	TV Products Division of Owens-Illinois	Columbus
	3229	TV Products Division of Owens-Illinois	Perrysberg
	3229	RCA Corporation	Circleville
	3229	Rodefer-Gleason Glass	Bellaire
	3229	Super Glass Corporation	Cambridge

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Ohio (continued)	3229	Techniglas, Incorporated	Newark
	3229	Variety	Cambridge
	3229	Holophane Division of Johns-Manville	Newark
	3229*	Johns-Manville	Waterville - 2 plants
	3296*	Johns-Manville	Defiance - 3 plants
	3296*	Owens-Corning Fiberglas	Newark
Oklahoma	3211	ASG Industries	Okmulgee
	3211	Ford Motor Company	Tulsa
	3221	Ball	Okmulgee
	3221	Brockway Glass	Muskogee
	3221	Brockway Glass	Ada
	3221	Kerr	Sands Springs
	3221	Liberty Glass	Sapulpa
	3221	Midland Glass	Henryetta
	3229	Bartlett-Collins	Sapulpa
	3229	Corning Glass	Muskogee
	3229	Scott Glass	Cedars
	3229	Scott Glass Products	Pocola
Oregon	3221	Owens-Illinois	Portland
Pennsylvania	3211	ASG Industries	Jeannette
	3211	PPG Industries	Carlisle
	3211	PPG Industries	Meadville
	3221	Anchor Hocking	Connellsville
	3221	Brockway Glass	Brockway - 2 plants
	3221	Brockway Glass	Washington - 2 plants
	3221	Diamond Glass	Roversford
	3221	Foster Forbes	Oil City
	3221	Glass Containers Corporation	Knox
	3221	Glass Containers Corporation	Marienville
	3221	Glass Containers Corporation	Parker
	3221	Glenshaw Glass	Glenshaw
	3221	Menlo Containers	Washington
	3221	Owens-Illinois	Clarion
	3221	Pierce Glass Division of Indian Head	Port Allegheny
	3229	Corning Glass	Charleroi
	3229	Corning Glass	State College
	3229	Corning Glass	Wellsboro
	3229	Corning Glass	Bradford
	3229	General Electric	Bridgeville
	3229	K. R. Haley Glassware	Greensburg
	3229	Houze Glass	Point Marion
	3229	Jeannette Corporation	Jeannette
	3229	Jeannette Shade And Novelty	Jeannette

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Pennsylvania (continued)	3229	J. H. Millstein	Jeannette
	3229	Kopp Glass	Swissvale
	3229	Lennox Crystal	Mount Pleasant
	3229	Mayflower Glass Works	Latrobe
	3229	Kimble Division of Owens-Illinois	Philadelphia
	3229	Kimb. Divis. of Owens-Illinois	Pittston
	3229	TV Prod. Div of Owens-Illinois	Pittston
	3229	Pennsylvania Glass Products	Pittsburg
	3229	Phoenix Glass	Monaca
	3229	Pittsburg Corning	Port Allegheny
	3229	Schott Optical Glass	Duryea
	3229	L. E. Smith Glass	Mount Pleasant
	3229	Victory Glass	Jeannette
	3229	Westmoreland Glass	Grapeville
	3229*	Owens-Corning Fiberglas	Huntington
	3296*	Certain-Teed	Mountaintop
Rhode Island	3221	National Bottle Corporation	Coventry
	3229	Corning	Central Falls
	3229*	Owens-Corning-Fiberglas	Ashton
South Carolina	3221	Laurens Glass Division of Indian Head	Laurens
	3229*	Owens-Corning Fiberglas	Aiken
	3229*	Owens-Corning Fiberglas	Anderson
Tennessee	3211	ASG Industries	Greenland
	3211	ASG Industries	Kingsport
	3211	Ford Motor Company	Nashville
	3221	Chattanooga Glass	Chattanooga
	3229*	Reichold Chemical	Nashville
	3229*	Owens-Corning Fiberglas	Jackson
Texas	3211	PPG Industries	Wichita Falls
	3221	Anchor Hocking	Houston
	3221	Chattanooga Glass	Corisicana
	3221	Glass Containers Corporation	Palestine
	3221	Kerr Glass	Waxahachie
	3221	Owens-Illinois	Waco
	3229	EMC Glass	Decatur
	3229	Multicolor Glass	San Antonio
	3296*	Johns-Manville	Cleburne
	3296*	Owens-Corning Fiberglas	Waxahachie
Virginia	3229	Corning Glass	Danville

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Washington	3221	Northwestern Glass Division of Indian Head	Seattle
	3229	Penberty Glass Division of Nuclear Pacific	Seattle
West Virginia	3211	Fourco Glass	Clarksburg
	3211	Libbey-Owens-Ford	Charleston
	3221	Chattanooga Glass	Keyser
	3221	Kerr Glass	Huntington
	3221	National Bottle Corporation	Parkersburg
	3221	Owens-Illinois	Fairmont
	3221	Owens-Illinois	Huntington
	3229	Beaumont	Morgantown
	3229	Blenko Glass	Milton
	3229	Brockway Glass	Clarksburg
	3229	Demuth Glass Division of Brockway	Parkersburg
	3229	Colonial Glass	Weston
	3229	Corning Glass	Martinsburg
	3229	Corning Glass	Parkersburg
	3229	Crescent Glass	Wellsboro
	3229	Davis Lynch Glass	Roversford
	3229	Elite Company	Cameron
	3229	Erskine Glass	Wellsburg
	3229	Fenton Art Glass	Williamstown
	3229	Fostoria Glass	Moundsville
	3229	Gentile Glass	Star City - 2 plants
	3229	Gladding-Vitro-Agate	Parkersburg
	3229	Hamon Handcrafted Glass	Dunbar
	3229	Harvey Industries	Clarksburg
	3229	Kanawha Glass	Dunbar
	3229	Lewis County Glass	Jane Lew
	3229	Louie Glass	Weston
	3229	Mid-Atlantic Glass	Ellenboro
	3229	Minners Glass	Salem
	3229	Pennsboro Glass	Pennsboro
	3229	Pilgrim Glass	Ceredo
	3229	Rainbow Art Glass	Huntington
	3229	Scandia Glass Works	Kenova
	3229	Seneca Glass	Morgantown
	3229	Earl Shelby Glass	Huntington
	3229	Sloan Glass	Culloden
	3229	Viking Glass	New Martinsville
	3229	Viking Glass	Huntington
	3229	West Virginia Glass Specialty	Weston
	3229	Westinghouse Electric Corp.	Fairmount
	3229	Paul Wissmach Glass	Paden City
	3296*	Johns-Manville	Vienna

PRIMARY GLASS MANUFACTURERS (cont.)

State	SIC Code	Manufacturer	Plant Location
Wisconsin	3221	Foster-Forbes Glass	Burlington

* Fiberglass

APPENDIX E

END-PRODUCTS OF EACH GLASS MANUFACTURING SEGMENT STANDARD INDUSTRIAL CLASSIFICATION

APPENDIX E

END-PRODUCTS OF EACH GLASS MANUFACTURING SEGMENT STANDARD INDUSTRIAL CLASSIFICATION

SIC NO. 3211 FLAT GLASS

Establishments primarily engaged in manufacturing flat glass. This industry also produces laminated glass, but establishments primarily engaged in manufacturing laminated glass from purchased flat glass are classified in Industry 3231.

Building Glass, flat
Cathedral glass
Float glass
Glass, colored: cathedral and antique
Glass, flat
Insulating glass, sealed units: mitse
Laminated glass, made from glass produced in the same establishment
Multiple-glazed insulating units, mitse
Opalescent flat glass
Ophthalmic glass, flat
Optical glass, flat
Picture glass
Plate glass blanks for optical or ophthalmic uses
Plate glass, polished and rough
Sheet glass
Sheet glass blanks for optical or ophthalmic uses
Skylight glass
Spectacle glass
Structural glass, flat
Tempered glass, mitse
Window glass, clear and colored

SIC NO. 3221 GLASS CONTAINERS

Establishments primarily engaged in manufacturing glass containers for commercial packing and bottling, and for home canning.

Ampoules, glass
Bottles for packing, bottling, and canning: glass
Carboys, glass
Containers for packing, bottling, and canning: glass
Cosmetic jars, glass
Fruit jars, glass
Jars (packers' ware), glass
Jugs (packers' ware), glass
Medicine bottles, glass
Milk bottles, glass
Packers' ware (containers), glass
Vials, glass: made in glass making establishments
Water bottles, glass

SIC NO. 3229 PRESSED AND BLOWN GLASS AND GLASSWARE, NOT ELSEWHERE CLASSIFIED

Establishments primarily engaged in manufacturing glass and glassware, not elsewhere classified, pressed, blown, or shaped from glass produced in the same establishment. Establishments primarily engaged in manufacturing textile glass fibers are also included in this industry, but establishments primarily engaged in manufacturing glass wool insulation products are classified in Industry 3296. Establishments primarily engaged in the production of pressed lenses for vehicular lighting, beacons, and lanterns are also included in this industry, but establishments primarily engaged in the production of optical lenses are classified in Industry 3832. Establishments primarily engaged in manufacturing glass containers are classified in Industry 3221, and complete electric light bulbs in Industry 3641.

Art glassware, made in glassmaking plants
Ash trays, glass
Barware, glass
Battery jars, glass
Blocks, glass
Bowls, glass
Bulbs for electric lights, without filaments or sockets: mitse
Candlesticks, glass
Centerpieces, glass
Chimneys, lamp: glass — pressed or blown
Christmas tree ornaments, from glass: mitse
Clip cups, glass
Cooking utensils, glass and glass ceramic
Drinking straws, glass
Fibers, glass
Flameware, glass and glass ceramic
Frying pans, glass and glass ceramic
Glass blanks for electric light bulbs
Glass brick
Glassware: art, decorative, and novelty
Glassware, except glass containers for packing, bottling, and home canning
Goblets, glass
Illuminating glass: light shades, reflectors, lamp chimneys, and globes
Industrial glassware and glass products, pressed or blown
Inkwells, glass
Insulators, electrical: glass
Lamp parts, glass
Lamp shades, glass
Lantern globes, glass: pressed or blown
Lens blanks, optical and ophthalmic
Lenses, glass: for lanterns, flashlights, headlights, and searchlights
Level vials for instruments, glass

- Light shades, glass: pressed or blown
- Lighting glassware, pressed or blown
- Novelty glassware
- Ophthalmic glass, except flat
- Optical glass blanks
- Reflectors for lighting equipment, glass: pressed or blown
- Refrigerator dishes and jars, glass
- Scientific glassware, pressed or blown: made in glassmaking plants
- Stemware, glass
- Tableware, glass and glass ceramic
- Teakettles, glass and glass ceramic
- Technical glassware and glass products, pressed or blown
- Textile glass fibers
- Tobacco jars, glass
- Trays, glass
- Tubing, glass
- Tumblers, glass
- TV tube blanks, glass
- Vases, glass
- Yarn, fiberglass: made in glass plants

SIC NO. 3296 MINERAL WOOL

Establishments primarily engaged in manufacturing mineral wool and mineral wool insulation products made of such silicious materals as rock, slag, and glass, or combinations thereof. Establishments primarily engaged in manufacturing asbestos insulation products are classified in Industry 3292, and textile glass fibers in Industry 3229.

- Fiberglass insulation
- Glass wool

NOTE: Taken from the 1972 edition of the Standard Industrial Classification Manual.